THE MOTION COMMOTION: HUMAN FACTORS IN TRANSPORTATION

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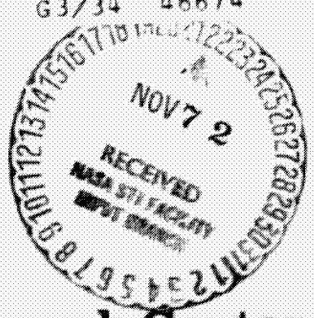

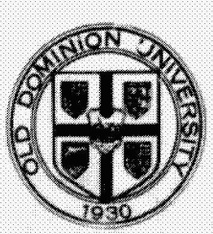

NASA Langley Research Center
and Old Dominion University

The Cover:

The concept MOTION COMMOTION and the cover photographs illustrate that many transportation problems have derived from the fact that man and society have frequently had to adapt to the system. We present the opposing view that the system should be designed to accommodate human needs in a broad approach to HUMAN FACTORS IN TRANSPORTATION. We are in debt to Mr. James H. Daus, Head of the Technical Illustrating Section of NASA-Langley Research Center for his invaluable assistance in the design and production of the cover and chapter title pages.

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THE MOTION COMMOTION:

HUMAN FACTORS IN TRANSPORTATION

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1972 SUMMER
FACULTY FELLOWSHIP PROGRAM IN ENGINEERING SYSTEMS DESIGN

ASEE-NASA LANGLEY RESEARCH CENTER
OLD DOMINION UNIVERSITY RESEARCH FOUNDATION

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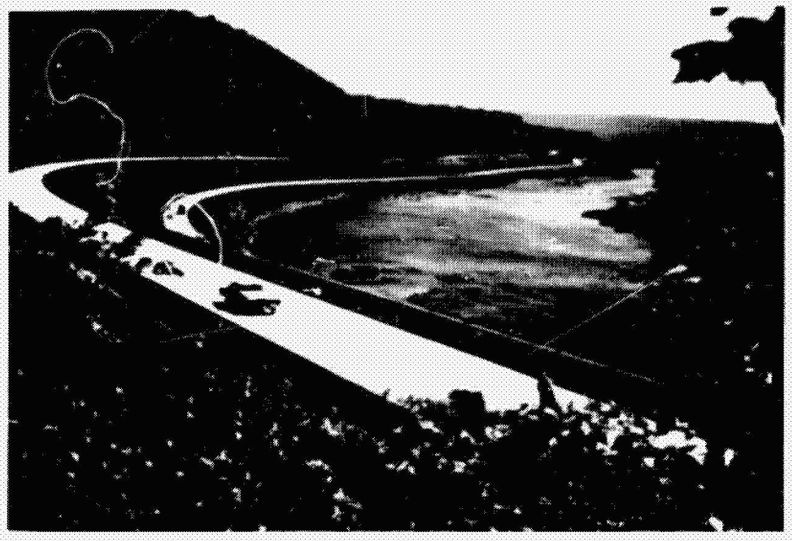
MOBILITY: THE USE OF OUR RESOURCES

ON THE WATERFRONT



GOING MY WAY?

GONE WITH THE WIND

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FOREWORD

This document summarizes the results of the 1972 ASEE-NASA Summer Faculty Program in Interdisciplinary Systems Design conducted at the NASA Langley Research Center during the period June 12 through August 25. The program was sponsored jointly by the National Aeronautics and Space Administration and the American Society for Engineering Education through a contract by NASA to the Old Dominion Research Foundation of Old Dominion University.

The objectives of this systems design program included the following:

(1) To provide a useful study of a broadly based problem of society that required the coordinated efforts of a multidisciplinary team.

(2) To provide a framework for communication and collaboration between academic personnel and research engineers and scientists in governmental agencies and private industry.

(3) To generate experience and foster interest in participation in and development of systems design activities and multi-disciplinary programs at the home institutions of the participants.

These three objectives were met by a group project directed toward a systems approach to the problem of incorporating human factors into transportation systems design. The group study and design effort culminated in this report which is meant to communicate the problems attendent to the human side of transportation, to the general public, and to decision-makers for purposes of community planning and legislation. The report outlines designs for land use and transportation systems management and gives specific recommendations for improving mobility for all segments of the population.

Such a study must consider a wide range of social, political, technical, legal, and economic questions. Therefore, in order to approach this study properly, a group of 17 investigators was assembled including faculty members representing 11 academic disciplines from 17 different universities and one law student. The result was a multi-disciplinary team well suited for the study of this most important problem, and it is felt that this report reflects the very broad background of these participants.

Chapter I portrays the importance of the Human Side of Transportation and introduces Chapters II, III, and IV which discuss the three major factors related to maintaining a mobile and quality life for everyone. These factors are (1) people, as individuals and groups, (2) society as a whole and (3) our natural environment and man-made physical environs. Chapter V summarizes the problems and the bottlenecks (or impediments) to their solution, while Chapter VI proposes approaches to removing these bottlenecks and affecting solutions through systems analysis and design. Chapter VI presents specific recommendations that the authors of this report feel are essential to achieving a goal of improved mobility within quality of life and environmental constraints.

Having a multi-disciplinary team has greatly aided the success of this study, but in addition the program has benefited from lecturers and consultants from a number of governmental agencies, universities, and private industries. These individuals, who are listed in Appendix C, were invaluable in providing needed data and information for the report.

Appreciation is expressed for the many courtesies and the comfortable atmosphere provided by the Co-Directors of the NASA-ASEE Summer Institute, Dr. John E. Duberg and Dr. Gene L. Goglia. The continuing excellent support and patience extended by Mr. Malcolm P. Clark and Mr. John Witherspoon of the NASA Training and Educational Services Branch are also warmly acknowledged.

Dr. Randall M. Chambers, Chief Life Scientist of the Langley Research Center, served as the technical advisor to the study program from its conception to its conclusion. For his constant encouragement, counsel, and cooperation during the entire program, the participants express their deepest appreciation.

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PROLOGUE:

MOBILITY AND LIFE

The essence of life is movement. From the cradle of civilization in the Tigris-Euphrates crescent to our most recently conquered frontier, the moon—man's most prevalent desire has been to go beyond whatever barrier restricts him. In movement man senses an expansion of his spirit, and the very existence of diverse world societies can be traced to the basic impulse to improve one's life. To go is to improve—thus we perceive the crux of American civilization. Were it not for an attempt at betterment, whether for material gain or for religious beliefs, no man would have ventured upon the thousand leagues of brine separating Europe from the New World. But history reveals that homo sapiens is migratory, even Nomadic; and America's development resulted from his following the ever-westward journey of the sun, the source of life.

Transportation and society are and have been interrelated. America's earliest statutes reveal that governing bodies took note of the importance of being mobile. As early as 1632, the statutory laws of Virginia show the following entry: "Highways shall be layd out in such convenient places as are requisite accordinge as the Governor and Counsell or the commissioners for the mounthlie corts shall appoynt, or accordinge as the parishoners of every parish shall agree."[1] Even in colonial times, we detect the necessity of unimpeded movement among people, and the realization of this vital need warrants an exceedingly close examination in our time.

Thus, we address ourselves to man in motion, transportation and people, the mixed blessings of the late twentieth century. Although the Oxford English Dictionary refers to the early definition of transportation as "removal or banishment, as of a criminal to a penal settlement," we must cease to look upon the term as synonymous with negation. For in the practical sense, it is transportation which allows the individual a medium of participation in society. Without the ability to convey himself and his goods, man is doomed to isolation and penury of flesh and spirit.

The succeeding pages present the status quo of America's transportation scene. The emphasis, however, concentrates on the people who do and must use our diverse transportation systems as an integral phase of their life. Consequently, the overview of transportation systems is shaded toward the people—the user, the non-user, and their problems. The specific concentration of this study is to delineate the profusion of transportation problems as they are perceived by the technical and scientific observer. The intent is not to bemoan the apparent hopelessness of urban transportation but rather to isolate those facets of the system which can be approached as a means of solution. This does not imply that we consider transportation as a secondary problem among those confronting us today. On the contrary, the facts of contemporary life support the view that transportation is closely integrated with economics, social welfare, ecology, and defense. One is overwhelmed by the sheer magnitude of the ways transportation affects and is affected by the life styles we live and the activities we pursue.

The conscientious reader will detect in the pages which follow a degree of prominence which we believe should be allotted to urban transportation in particular. With over 105 million vehicles choking urban corridors, the time is now to develop proper management procedures. We are aware that greatly increasing demands must be placed upon the faltering supplies of transportation devices for mass transit. As more and more people move in daily cycles so they increasingly suffer from failure to allocate properly transportation resources. Modern man recognizes the paucity of mass transit systems that effectively serve him and thus substitutes the automobile as his staple. In consequence, he contributes to air pollution, spatial diminishment, personal expense, and emotional despair. Why, might we ask, does he not take the bus or train instead? Try it; you won't like it either.

The exodus from the inner city to suburban sleep and recreation is reversed five or more times per week to work. In what way has the citizen gained? Is there not some way in which life can be improved through trans-

[1] William W Hening, *The Statutes at Large*, Vol 1 (New York, 1823), p. 199

portation? Indubitably, sufficient technology exists to begin immediate improvement. Also, the Department of Transportation estimates that Americans spend annually $190 billion on urban transportation Consequently, the funding and the technology seem in evidence. So why not solve the problems and why not soon?

The early chapters of this study are designed to provide elucidation for the reader regarding the aspirations of mobility while appreciating the complexities of movement in and on land, sea, and air. Significant discussions of human factors in transportation follow suit and concentrate on the mixed modes available to travelers and riders as well as the concomitant societal, environmental, physiological, and psychological aspects which are related to mobility.

In a noteworthy attempt to answer the question posited above as to why we do not improve transportation, we include a full chapter on the social institutions which have bearing upon transportation. A tacitly accepted view is that the most salient problem in changing the errors of current systems lies in the political, jurisdictional, and private interest organizations which form the institutional structure controlling transportation. Thus, we view the actors in the national, state, and local settings as they adduce legal and economic influences in the overall picture. Has the reader ever pondered our national policy on transportation? Who really deserves plaudits or calumnies for the current status of mobility? Will anyone answer the question, "Who's in charge?"

Recognizing the relationship between transportation and the environment, we also present a chapter which concentrates on the debilitating effects which haphazard planning has elicited upon that resource which even a reincarnated Thomas Jefferson would now call finite—our land.

We condemn any land use which is the result of shortsightedness and temporary expediency. The reader may profit immensely in this chapter by noting a concept which could commute the sentence placed upon us which is killing our cities. The urban design concept functions on the premise that human beings seek experience in life. Whereas we formerly moved the people to the experience, it may now be possible to reverse the direction. Bring the mountain to Mahomet; bring the experience to the people.

Toward the end of the report, one will note a chapter which cogently outlines the most substantial problems facing the transportation user. This segment is closely related to a systems design approach which could provide a means of removing these impediments to better transportation. Both the generalist and the specialist should profit from viewing the interrelated variables which serve the continuum of modes and goals in transportation management and planning. Our view of design is that it must effect a change while integrating the levels of control already present. Viewing the situation from the known should aid in returning transportation to the servant of man which it is designed to be. While not solving the problems of mobility in our time, this document may very well become a tool for perceiving and implementing solutions.

As a culmination of multi-disciplinary groupthink, our NASA-ASEE study should serve as a lesson to the interested observer. We have blended professional expertise to grasp immensely complicated phenomena of life and have offered a potentially useful plan of action to the public. Hopefully, the individual who must use transportation will see that he is cast in the leading role for perhaps the first time in this context.

We reiterate that life is predicated upon movement. Although we have no magic solution to improve upon this demand of existence, we may remind the reader that he already possesses the most versatile of all transportation systems, one which Sir Thomas More described in **Utopia** over 4½ centuries ago. Note his description of this ideal mode of movement: "Of these cities there is none of them distant from the next above one day's journey **afoot**."[2]

Is it of any consequence that the word "Utopia" means nowhere?

---

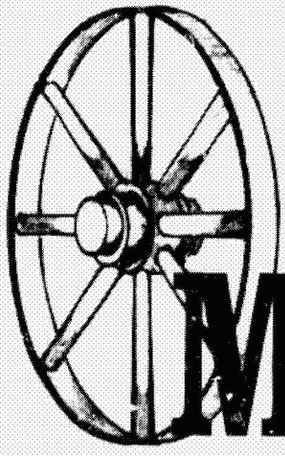
[2] Thomas More's *Utopia* was published in 1516

SUMMARY AND RECOMMENDATIONS

We recommend that

1. The "role" of transportation be defined in a dual sense, as (1) a service to provide necessary mobility, and (2) a tool for land use planning and desirable social and economic development.
2. Congress give first priority to passage of a comprehensive national land use policy and planning act.
3. A joint House-Senate committee be established to formulate policy and coordinate all transportation matters.
4. The participation of citizens and citizen groups be encouraged and solicited at the outset of the transportation planning process and continue in an organized way throughout the process.
5. Public transportation in the city be regarded as an essential service, like the police and fire departments. It should not necessarily be required to be self-supporting.
6. Attention be given to providing short-term solutions to transportation with the use of available technology.
7. The modally designated transportation trust funds be eliminated and that the funds therein be available for general transportation purposes to enable the development of more flexible intermodal (or multi-modal) policies and planning.
8. Extension of work in physical and psychological human factors in all forms of present and futuristic transportation and man-machine systems.
9. DOT should consider a demonstration of no auto traffic in selected downtown urban areas or a portion thereof. Freeways, arterial highways, and streets would all dead-end into parking facilities with simplified direct access to downtown areas via public transit.
10. Pedestrian movement, and particularly the reduction of conflict between pedestrian and motor vehicle movements, receive significant consideration in urban traffic planning and operation.
11. DOT should construct for every mile of highway constructed a fixed percentage of bicycle paths.
12. Immediate short range action programs be instituted to improve local bus systems.
13. Since the psychological benefits of a transportation system, such as self-esteem and personal control, appear to be factors in its selection as a mode choice, transit designers and administrators should attempt to make the traveler on public transportation feel important and significant.
14. Each state follow the lead of the states, such as New Jersey, to measure exhaust emissions in all cars registered by the state and to require modification of the vehicle to make it meet standards.
15. The federal government provide funds for highway maintenance in the same proportion as federal capital is provided for construction.

1



MOBILITY:
Promises and Problems

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Mobility, the Fifth Freedom

The charge to the 1972 NASA-ASEE Summer Faculty Design team at Langley Research Center at the beginning of this study was to devise a method to incorporate human factors into transportation systems design. As is detailed in this report, we found it necessary to consider a broad range of concepts, activities, and processes as human factors in transportation systems. In other studies the definition has been limited to physiological responses only, or to subjective opinions of vehicle ride quality, or to socio-political community responses. We have felt it necessary to include all of these and some other considerations as well. It appears to us that taking any narrower view will destroy any possibility of properly viewing transportation and man's relationship to it as an interacting system.

We have focused on the concept of "mobility" in the presentation of our results as the chapter titles indicate. Mobility connotes ease of physical movement and a lack of barriers to changes in social status, embodying a wide spectrum of what we have perceived as human factors in transportation. We go even further and propose, as the title of this section suggests, that mobility should be considered as a basic freedom in our society. As noted by Secretary of Transportation, John Volpe, [1] without mobility, the first four—freedom of speech, freedom of worship, freedom from want, and freedom from fear—cannot all exist. We do not mean to suggest that every citizen should, by right, have access to transportation to any destination of his choice at any time but we do suggest that every citizen should, by right, have access to transportation to deliver him to and from a place of residence and available job locations or to secure the basic necessities and amenities of living in today's America.

The pursuit of such a goal would require a major commitment of physical and human resources. Regardless of the size of the commitment, success would not be assured. We have used up vast quantities of our natural resources, and there is much in our traditions which would form difficult obstacles. The achievement of mobility for all of our citizens will require that we use all our present knowledge of human factors and that we learn much more.

Perspective of Present Transportation

A perspective of our present transportation may be obtained by considering the following four elements: technology of transportation, the **roles** of transportation, population growth and concentration, land use and environmental concepts and policies. These factors are elaborated upon briefly in the list below.

Factors Shaping the Transportation Environment

1. Technology of transportation
   - Hardware available
   - Systems arrangement and operations
   - Resource demands
   - Comfort levels for user
   - Direct effects on the natural environment and non user
2. Roles of transportation
   - Web of the nation
   - Local service
   - Director of development
3. Population growth, concentration, and characteristics
   - Demographic and geographic facts
4. Land use and environmental concepts and policies
   - Views of land and natural resources including esthetic values which determine the trade-offs in siting decisions

Much of the interaction between man in America and his transportation systems can be highlighted by considering these elements in a historical context beginning around 1825.

Technology of Transportation

In 1825, the principal modes of transport in this country, aside from walking, were boats or barges on water and horse drawn wagons. There were major routes through the Appalachians by both modes. Most famous examples are the National Road from Cumberland, Maryland, to the Ohio River Valley and the Erie Canal. The primary flow of people was to the west and of goods such as grain to the east. By 1875, the railroads had

TABLE 1.1
TECHNOLOGY OF TRANSPORTATION

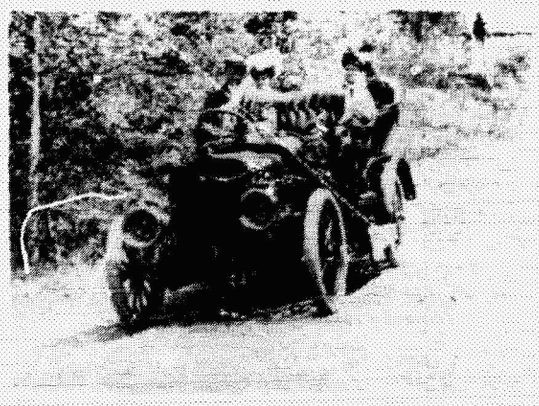
	Primary	Secondary	Research development phase
1825	water horses		railroad
1850	railroads	water horses	
1875	railroads	horses	
1900	railroads	horses	automobile, airplane
1925	railroads highways	water pipeline	airplane
1950	highways railroads	water pipeline air	
1970	highways railroads air water pipeline		TACV, V/STOL air
2000	?	?	?

emerged as the leading mode of transport with an extensive network of tracks across the country. Horses still served a significant function including the primary commuting mode in larger cities such as Chicago. The movement of freight on the canals had reached its peak prior to 1850 and by 1875 had come to a halt due to superior speed and reliability of parallel railroads. The 25-year span from 1900 to 1925 saw the rise of the automobile and the early development of the airplane as well as introduction of significant pipeline transport of petroleum, and renewed interest in inland water transport. In 1925 the railroads and highway modes were the major elements of the transportation network. Railroad construction had essentially come to a standstill while road building was going into an upswing which has continued until today. A number of major cities had rail commuting systems. Mail was being carried by air.

Now we find five modes with substantial shares of the transportation market. Highways and airways share most of the passenger business while the freight movement is divided among railroads, highways, waterways and pipelines. (Table 1.1) The table above summarizes the development of various modes of transport in the United States.

The resource demands for railroads, waterways, pipelines, and highways prior to

1910 Chicago Street Scene.
Waiting time often exceeds travel time.



The Good Old Days.

1875 were primarily land and cheap labor. Both were in good supply due to government policy on land grants and immigration. These two resources have become increasingly scarce as time has passed. Other demands, such as fuel and material requirements, are now reaching levels which have brought concerns because it appears that the earth's supply of petroleum and many metal ores may be used up in a fairly short time span.

Comfort levels for passengers have become important as automakers, airlines, and railroads compete for customers. The subjective standard is currently set by the automobile. Direct effects on the environment and the non-user have been manifest first through demands on the landscape and further through noise, emissions, safety hazards, and otherwise. All of these factors have presented problems which have become more and more critical as time passes.

Roles of Transportation

The roles of transportation, as listed previously, may be classified as: (1) the tie that binds the major sections of the country together, the web of the nation, (2) the provider of the distributional services required locally for goods and people, including today the diurnal heartthrob of commuters moving in and out of the cities, and (3) the pacesetter or pointer controlling the direction and to some extent the speed of development in particular areas.

The first function of tying the nation together, forming **the web of the union**, was met to a large degree by the railroads prior to 1900 with a pattern of tracks which remains essentially unchanged. Prior to the turn of the century the tie was primarily economic. People tended, with a few exceptions, to migrate to new locations and employ the transport network to obtain supplies and ship products to market. Today, to be sure, there is a tremendous flow of freight on the five modes of transport, but there is also a large flow of people on the airways and highways. All of this is instrumental in maintaining and tightening the fabric of the web. This function is performed for the most part by links which are outside of urban areas. Most of the difficulties, however, arise around the cities at the interface or boundary between the system and most of the people.

The second role, **that of service to a local area**, is met today primarily by the highway modes. By far the majority of stores and homes receive their stocks of supplies by truck or automobile, and most workers travel to and from work by car. In a few cities, rail contributes substantially to this role, but even there its portion of the market has been decreasing. Even in San Francisco where BART (Bay Area Rapid Transit) is nearing completion and Washington, D.C., where the Metro is under construction, the plans for provision of transit service do not offer promise of enticing a major portion of the automobile commuters.

Recognizing belatedly that this function has not been executed well by the automobile alone, in 1970 the Federal government commited 10 billion dollars to be spent on public transit over a 12-year period. It remains to be seen if the program will be effective but lest anyone view that figure as evidence that public transit will now get equal opportunity with the automobile, it should be pointed out that based on a General Motors estimate of total new auto sales over the same period there will be spent a total of over 600 billion dollars just in purchase costs if the average price per car is $2,500.

Traditionally, transportation has been viewed as a business which should be privately owned and operated under the incentive of profit. This concept has tended to minimize its potential for providing mobility in its service role. It appears that transportation services which people need cannot always be furnished on a profitable basis.

The third role, **that of controlling development**, has historically been most evident in the dynamic periods of growth and particular modes. Cities were first located according to availability of water transportation, be it by sea, river, or canal. During the last century the locations of the railroads dictated the locations of a number of cities on the great plains. Cities such as Chicago, New York, and Philadelphia have been shaped by their commuter railroads and subways. Today the location of major highways and arterials determines to a large extent the growth patterns of our cities.

Population Growth, Concentration, and Characteristics

The pattern and quantity of transportation required at a particular time are determined by the number of people to be supported, their relative locations, and their

activities. Figures 1.1 and 1.2 are reminders of the facts that our total population is growing rapidly, and an increasing portion is living in urban areas. Within urban areas the distribution of people is a strong function of available transportation as indicated by the third role of transportation. Where automobiles are the prime mode of moving, the density tends to be less than in areas which are dependent primarily on rail transit while buses support some intermediate density of living. Herein lies one of our major difficulties since the automobile is ideally suited to the transportation problem of moving people among random origins and destinations in a sprawling suburb. But it consumes too much space, requires too much land for its way, and emits too much pollution to be satisfactory in areas of dense concentration such as many of our city centers.

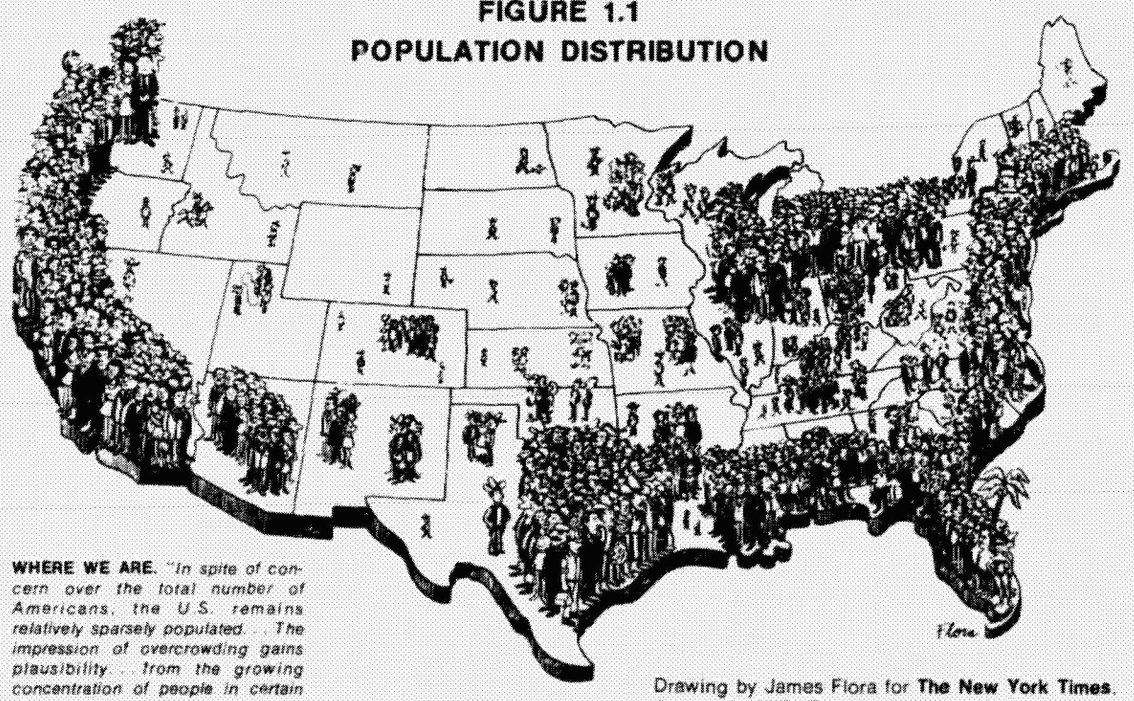
In addition to the spatial distribution of the population, the age distribution, the size distribution, the economic distribution and other socio-economic and health characteristics of the population must be considered. Here again we find that our present transportation does not serve well the very young, the old, the infirm, or the people at the lower economic levels.

Land Use and Environmental Concepts and Policies

Recognition of the third role of transportation, as director of development, leads to a consideration of land use and environmental concepts and policies. The traditional view of land held by the Europeans and their descendants on this continent since the settlement of Jamestown has been that it is a commodity to be bought and sold, used and depleted (or perhaps enriched) by its owner as he sees fit. The corresponding view of the natural environment has been that the environment is essentially infinite, capable of absorbing man's activities with no permanent catastrophic effects. An associated idea is that American panacea which holds that growth is progress with little allowance for detrimental side effects.

The preceding concepts lead to policies imposing no restrictions on polluting or land destructive activities as such. And any regulations on land use must be designed so that the economic value of adjoining land will be maintained or enhanced. Zoning regulations even for this purpose were not recognized as valid nationally until a test case reached the Supreme Court in 1926. In that

FIGURE 1.1
POPULATION DISTRIBUTION



WHERE WE ARE. *"In spite of concern over the total number of Americans, the U.S. remains relatively sparsely populated. . . The impression of overcrowding gains plausibility . . . from the growing concentration of people in certain regions, states and communities."*

Drawing by James Flora for **The New York Times**, August 2, 1970. Reprinted by permission.

POPULATION OF UNITED STATES
1780-1970

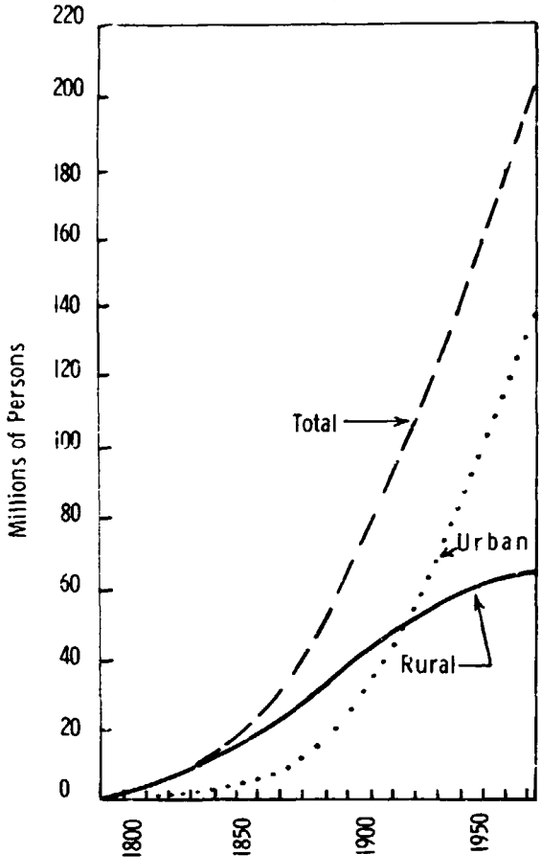


FIGURE 1.2

year the constitutionality of such zoning ordinances was upheld in the historic case of "Village of Euclid" v. "Amber Realty Co.," 272 U.S. 365. To reiterate, in keeping with the traditional concept of land, for the most part the larger public interest was and is interpreted to be protection of property values and the economic value of land. The dependency of most cities upon property taxes serves to reinforce this prevailing purpose of land use controls. These controls were and are intended primarily to prohibit certain uses of land, not to induce appropriate land use.

Because of the overriding importance of land use and environmental planning, the following extensive quote is given from Senate report number 92-869 of the Committee on Interior and Insular Affairs, June 19, 1972.

"Few States considered it important for the broader public interest whether any local government actually engaged in planning; whether the controls and the development they controlled were in accordance with a plan; whether such a plan, where it existed, promoted the public interest of the local community; and even whether an existing plan of local government adversely affected the public interest of larger areas such as the region or the State as a whole.

"In the absence of State concern or guidance, the cities (and, for that matter, the courts) came to treat the decidedly negative local land use regulations as though they embodied whatever planning was considered necessary. **Thus, rather than guiding planned development, land use controls have lent protection to virtually unplanned development.** Whether land use decisions have been left to the market place or to local regulations absent a planning base, inefficient, unsightly, and often costly land use patterns have resulted. For example, open spaces valuable for recreation, greenbelts or just a break in the carpet of urbanization have succumbed to private development catering to the one-acre recreational homesite dreams of our nation's city-dwellers. Land uniquely suitable for certain uses, such as major airports, has been preempted for other uses which possess far less demanding criteria. And unwanted but essential projects, such as powerplants, have met with wasteful delays and been sited finally in locations of least public and political resistance, but often without consideration for sound developmental and environmental needs.

"Where planning has been conducted it has too often been mission-oriented or single purpose. Planning of this nature seldom relates specific missions or purposes to a balanced range of national goals. Planning for particular kinds of activities leaves the planner and the citizen with narrow "either-or" decisions, often on a case-by-case basis. Because the planning concerns only one kind of activity only the need for facilities to support that activity is examined.

In short, consideration of long-term alternative uses of the land is seldom mandated and even less often achieved in single-purpose planning. **The highway planning of the recent past provides an excellent example of the failure of single purpose planning.** Planners have routed highways through parks where land is invaluable for recreation but cheap for roadbuilding; carved up low income districts with commuter access roads—thus effectively destroying any sense of community; poured additional highway lanes into cities unable to cope with more automobile traffic and air pollution; and sited major interchanges without regard to the unplanned and often unanticipated growth centers which they generate

"Too frequently, even the best of recent land use planning—planning which considers a broad range of values and requirements has been for missions or purposes writ large: the pursuit of economic growth (planning for high tax ratables such as industrial parks on scarce, undeveloped coastlines and shorelines on land suitable for housing), of environmental protection (the planning for maximum open space and exporting pressures for housing, commercial districts, and schools into the next jurisdiction), or of social betterment (planning for housing developments and subdivisions and massive use of recreation areas without carefully considering, and seeking ways of diminishing, the impact upon the environment).

"Furthermore, because land use controls have seldom been linked to a planning base, plans too frequently are divorced from any institutional mechanisms for their implementation. Too many resplendently color-coded plans, single purpose or not, have been left to collect dust on administrators' shelves. Without implementation—without adequate institutions, methods, and procedures—plans, planning techniques, and the planners themselves are not tested by experience.

"The much greater pressure to which urban land areas are subject, the almost total delegation of State authority over land use to cities, and the frequent failure of cities to plan, and where they have planned, their inability to plan on a regional basis, have insured a distinctly urban bias and coverage to land use controls. Traditionally, those most concerned with land use controls have been urban residents, municipal officials, and "city planners."

"Yet, as the Chairman of this Committee has stated:

"[Land use problems do] not pause at the periphery of the ever-widening circle of land dedicated to or held for urban use. Urban dwellers today place demands upon rural land miles and sometimes several states away from their homes. Los Angeles' power needs have brought air-polluting power plants and land-polluting strip mining to the Navajo and Hopi lands of Black Mesa in Arizona and New Mexico. Waste disposal problems have forced consideration of such solutions as the shipment of refuse hundreds of miles beyond our cities' boundaries. And along our shores and in our mountains escape from the cities has become the unattainable goal of those who in seeking second homesites create second suburbias.[1]

"Furthermore, at the interface between rural and urban land, on the so-called "urban fringe," exists what has been termed "the worst of our land use problems: the urban sprawl, the 'slurbs,' which reduce the quality of our physical and social environments. Rather than accommodating urban densities, urban sprawl spreads urban populations across vast areas of land—idling and ending the productive use of far too much of it."[2] Since, with each passing decade, new urban growth will cover an area greater than the

[1] National Land Use Policy Background Papers on Past and Pending Legislation and the Roles of the Executive Branch, Congress, and the States in Land Use Policy and Planning (hereinafter referred to as "National Land Use Policy Background Papers"). Committee on Interior and Insular Affairs, U.S. Senate, April 1972 (p 5)

[2] Ibid., p. 4

entire state of New Jersey, this interface will continue to lengthen, absorbing more unplanned, rural, and open land. Proper land use decision-making along this interface is impossible unless it is conducted on a planning base which, absent an urban bias, truly relates and coordinates rural and urban land uses.

"This urban bias is also detrimental to efforts to achieve wise and efficient land use patterns in predominately rural areas—areas where the opportunity to achieve a better design for tomorrow still remains.

"Finally, this urban focus and the almost full delegation of land use controls which contribute to it have also encouraged fragmentation of land use authority: The Douglas Commission estimated that, in 1969, some 10,000 governments were exercising land use controls.[3] This Committee subscribes to the proposition of local control over matters of local concern. However, the deleterious effects upon proper land management produced by such a balkanization and proliferation of governmental entities practicing land use controls are both numerous and profound where there is no on-going effort at the State and regional levels to relate and coordinate local land use plans and policies.

"First, the constant wasteful competition to import certain land uses (largely economic) to build a tax base and to export unwanted land uses (often environmental or social) to avoid a drain on revenues is magnified several times over as the number of competitors increases.

"Second, this situation of numerous and often overlapping jurisdictions having land use powers leads to a practice particularly destructive of land use planning: "forum-hopping." Both developmentalists and environmentalists "forum-hop": the former dangling the promise of high tax ratables before communities so revenue-poor they are compelled to reject even the effort of quantifying and balancing non-economic values; and the latter invoking the threat of endless administrative and judicial delays before decision-makers who can offer neither a single procedure to which to require adherence nor a single decision-making forum in which to compel participation.

"But, third, and perhaps more serious is the conflict with democratic principals produced by this multi-jurisdictional assumption of land use powers. The intensifying pressures upon our land base and the increasing size, scale and impact of decisions affecting land use have created a situation in which local, public and private decision-makers are making land use decisions for far larger constituencies than they in fact represent. A citizen may significantly suffer from or enjoy the impacts of decisions to site an airport, grant a subdivision permit, widen a highway, fill wetlands, purchase park land, etc., made not by his community but by the municipality located downstream, downwind, across the road, or up the street from him. Yet, neither he nor the public officials for whom he has voted may be able to effectively participate in these decisions. Again, absent institutions and procedures which provide a measure of overview and effective coordination, this problem is multiplied with each additional division of land use authority in the same geographical area."

The report further considers the requirement for change in land use policy.

"The utility of this traditional concept of land must be questioned in light of the severe pressures placed upon the land by continued population growth; increasing urban and industrial development; expanding transportation systems; the fragmentation of governmental entities exercising land use powers; and the increased size, scale and impact of private actions. A growing number of public officials and private citizens, upon feeling and perceiving the impacts of these pressures, are speaking of a "national land use crisis" which threatens orderly economic growth and environmental quality.

> "To meet the emerging crisis, this traditional concept of land and the land use controls which reflect it must be revised and made responsive to changing values and needs, modern technology, increasing land use demands, and the desire of the American people to be involved in decisions which will shape this Nation's future. Land must be considered as more than a commodity to be bought, sold, and consumed; rather it should be viewed as a finite resource to be husbanded."

Adherence to this latter view, that land is a finite natural resource which is to be utilized and conserved in a way calculated to enhance the lives of present and future generations, would lead to positive planning and implementation. Much new information and knowledge of the interactions within spatial and temporal activity patterns would be required.

The traditional view of the natural environment has already given way, as we have recognized that the biosphere forms an essentially closed cycle within which most men must exist throughout their lives. It appears that man has the capacity to damage irreparably some links in the chain. We already have legislation designed to limit many polluting activities.

The Interaction of the Elements

The interlocking nature of the four elements which have been discussed can be seen, but its dimensions are not completely understood. It appears that the technology of transporation has not historically depended upon the other elements, but it has influenced them tremendously. We have now reached a time when the technology of transportation can be influenced by other elements. For instance a requirement from one of the **roles of transportation** could possibly set in motion a development program to generate a system with particular characteristics. Similarly, the growth, concentration, and characteristics of population more or less influence the balance among the roles of transportation and enhance more or less the demands on land use and environmental planning.

The role of transportation as a director of development interacts directly with prevailing land use and environmental policies. Extensive discussion of the status of land use planning has been included precisely because transportation facilities have the potential to be powerful tools in implementing land use plans.

Human Factors In Transportation Systems

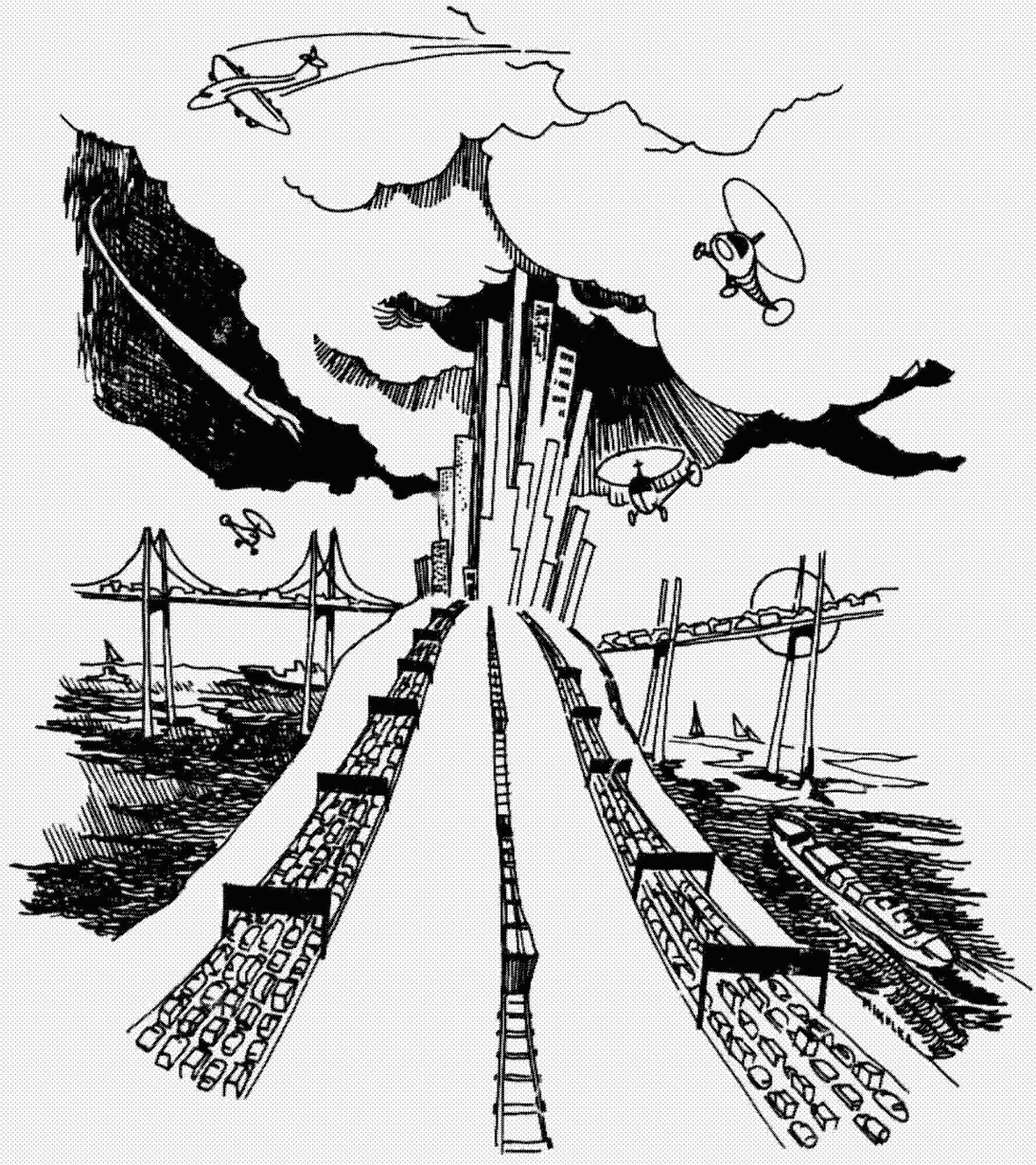
Views From Various Disciplines

As stated near the beginning, we have taken a broad view of human factors commensurate with the spectrum of disciplines represented in the study group. Some typical reactions of some members of the group from various disciplines when faced with the charge of "devising a method to incorporate human factors into transportation systems design" will serve to define some initial individual views of what constitutes human factors. Collectively they outline our views

An economist might investigate the structure within which decisions on transportation are reached. He may want to know, "who are the actors in the design process? What are their roles and what motivates them in their decision making?" These questions call forth considerations of decision makers from the individual traveller to the elected officials at the national level and back again to the individuals and groups who are non-users but who are subject to externalities.

A lawyer may raise questions regarding the institutional framework within which transportation policy is shaped and implemented. He may have much to say about the interactions of the hodgepodge of agencies and other governmental units which have roles in the planning processes of metropolitan areas. Another issue of great importance is the identification of the source of national transportation policy.

In addition to being concerned with institutional structure, a political scientist may point out the strong and pervasive linkage among social, economic, and political variables. He may pose questions such as the following: In general what will a modified or new transportation system do to this society? Who are the people who will be most significantly affected? What will be the reactions of the reflectors, the politicians? Will the politicians accept an argument that change is necessary? If so, what sorts of change and in what direction? Will urban blight be halted or speeded up? Will the suburbs become the subslums? Will the suburbs become the replacement for the inner city now lacking in



much of our society? How will General Motors, Ford, Chrysler, Standard Oil, Gulf, etc be affected? Who wins and who loses from our transportation system?

A psychologist may be concerned about factors which determine whether individuals like or dislike, accept or reject particular modes of transporation. He may be concerned about peer group standards, personal space, perceived security, reliability, self-esteem and other factors as well. Why, for instance, have human factors in transportation become important in the recent past? After all, in the early days of rail travel, passengers were happy to ride in slow, high vibration vehicles exposed to both weather and soot from the train's smokestack. Similarly, stagecoach riders never thought to complain about their crowded and bumpy conveyance. The increasing interest in human factors may be traced to a rise in traveler's expectations, as the role of transportation has evolved from moving freight, to moving people in comfort and convenience.

The automobile has provided a standard that has shaped the expectancies of the American traveler. He knows what level of comfort, convenience, safety, and so on his automobile can provide him, and his nction of acceptable ride quality is a function of this knowledge. In addition, people typically compare their experiences with others in similar situations in deciding on the acceptability of a travel mode.

For example, the train commuter will be dissatisfied with his service if he perceives that his neighbor makes the same trip more quickly and more comfortably by automobile. However, the train commuter will be happy with the identical service if he knows that his friend spends an extra hour fighting traffic.

Thus, the existence of the private automobile, by serving as a standard for comparative evaluation of other transportation modes, has been an impetus for concern with human factors in public transportation.

Engineers with a vehicle orientation have tended to raise additional questions such as what are "tolerable" and what are "comfortable" ranges of temperature, ventilation, air contamination, vibration, noise, and acceleration. The answers of course depend on psychological parameters as well as strictly physiological responses to the physical environment.

Many engineers today have a systems orientation and seek to fit the many facets of transportation into a framework with which the powerful tools of systems analysis can be applied to gain insight and understanding of the effects of interactions within the system. They have asked, "What are the possible network arrangements? What are the resources required and what are the life styles implied by various conceivable transportation systems?" But above all, they want to know what, explicitly, are the goals to be sought in developing a national transportation system In order for systems analysis to serve well, the goals must be stated in such a way that the margin by which a particular system misses or exceeds them is measurable in some sense. Traditional measures of economic efficiency are no longer adequate.

A major emphasis concentrates on the effect of transportation systems on the nonuser, the environment, and the vague concept of "quality of life." In connection with these areas we are disturbed by some of our traditional measures of progress such as the GNP. Does it in fact reflect standard of living?

Having scanned the landscape, we now turn to an attempt to bring a semblance of order to the pot of ideas which are seen by various people and disciplines as human factors in transportation systems.

A Classification of Human Factors in Transportation

We may view human factors in a number of ways. For instance we might consider categorizing them on the basis of academic, scientific areas such as psychological, sociological, political, and physiological factors. However, many experience in travelling or just living in today's world would trigger responses in all of these categories. For instance a person living 500 feet from an arterial highway with virtually no trucks will usually become accustomed psychologically and physiologically to certain noise levels. He may complain in his social interactions but usually will take no political action. Add trucks (which will significantly increase noise) to the traffic mix and our citizen will respond psychologically, physiologically, sociologically, and probably politically.

We have chosen to classify human factors in a different way. We identify two divisions. The first division includes those which describe stimuli and responses of individuals resulting directly from interaction with the transportation system and the

reference group as it affects the individuals' travel choices. The second division is composed of those activities and processes through which decisions on transporation planning are made.

The stimuli and responses of the first division have been grouped under the following seven categories

Internal Environment
External Environment
Costs and Benefits
Convenience and Mobility
Safety and Security
Social Interaction
Psychological State

The categories in this list are not exclusive, but we have found them useful as a framework for discussion. They are considered further in Chapter 2.

The activities and processes of the second division, taking place within institutional and political arenas are more difficult to categorize. There is of course extensive interaction between the activities and processes envisioned here and the stimuli-response set in the above list. It is tempting to imagine that the interaction consists only of information flow from the first division to the second. This flow combines with a set of traditional values and ideals and information from other areas such as housing demands to define the environment for decision making.

The efficiency and efficacy of the decision making process are strong functions of the governmental structure. As mentioned previously there exists a myriad of Balkanized governmental units within our urban areas.

In New York City alone there are over 1400 separate governmental units that have spending power of some sort. Many of these units are able to exercise a veto power over the transportation systems that affect their jurisdiction. At the same time there are intergovernmental **externalities**—both benefits and costs—which arise from related economic functions being located in neighboring political jurisdictions; and often transportation decisions must bear the burden of a mismatch among the various interests of the areas, their taxing and spending powers, and the joint benefits and costs created.

Rational transportation financing is further eroded by the **dynamics** of economic activity location which features activities moving from one governmental area to another. We tend to think of transportation as a means of getting from one fixed location to another. It turns out that within a metropolitan area the locations of activities are much more flexible than such transportation factors as rights-of-way, bridges, and rail-way terminals. Julius Margolis has observed that continuous spatial shifting occurs among the locations of various residential and commercial activities. [2] This process creates conflicts of interest among the areas because taxes are not assessed in proportion to the benefits received. More specifically the benefits from the use of transportation facilities are not proportional to the costs of property taxes and gasoline taxes businesses pay in a particular area. These benefits and costs do not promote **optimal clustering of activities**.

Moreover, there is little assurance that in reconciling their divergent interests the myriad of governmental units will produce a rational transportation system. Since each unit has veto power and since, in any plan, one unit's gains will not compensate for its losses, a metropolitan area with a large number of units operates under a serious organizational constraint. Thus, the crisis in planning and funding for effective land use and transportation is caused not so much by the lack of revenue sources but by a lack of organization.

There are other sources of the mismatch between the interests of the community and the institutions that make transportation decisions. Local officials tend to respond more readily to the immediate interests of the wealthier property owners than to the average citizen who has few thoughts about the long run evolution of the community. Thus, zoning codes tend to be changed to allow for industry, commercial and multi-family residences to the exclusion of recreational and park areas. The wealthier people don't need the parks anyway. Similarly road planning and spending are usually quite responsive to local business interests. Until recently the only conflict observed was between developers of shopping centers and downtown business interests.

We cannot even be sure that the voters will support rational land use and transportation policy. If each voter has a sufficiently limited view of the relationship between individual and community interests, politicians attempting to follow their wishes will only make matters worse. This is because of a rather basic "prisoner's dilemma"* which

individuals find themselves in with regard to urban transportation.

> *The prisoner's dilemma occurs when parties individually acting for their own interests make each other worse off. The term derives from the situation where two suspects are apprehended and asked separately to give evidence of their mutual guilt. If both would keep silent they could only be charged with a minor offense. But each is promised that if he alone confesses he will go free. On the other hand, if both confess, both will get the maximum sentence. The result, if each follows his own immediate interest, is that both confess.

Each voter would be better off with a new freeway that he alone can use. But new freeways tend to breed new housing and new congestion. Acting in concert, voters and their representatives may make everyone worse off. [3] Politicians are seldom blamed for the gradual deterioration of an urban area or for congestion on a freeway. They would be blamed, however, if they turned down a federal grant for more freeways. The only possible course for most politicians is a "flexible" land use policy coupled with advocacy of more freeways. Very recently voters and politicians in San Francisco, Chicago, and a few other areas have become exceptions to this dismal rule. These exceptions seem to indicate that voters can in fact perceive the social value of planning for land use and transportation. This anticipates one of our basic observations: since more rational planning must ultimately depend on voter acceptance, an extensive education program is required.

The institutional arrangements are discussed further in Chapter 3.

Requirements For The Future

We must attack the problem of devising a system which properly balances the competing concerns suggested by the various human factors. Over the last few decades, powerful tools of analysis have been developed to assist in the design and management of large projects such as the Apollo program. These tools of analysis and synthesis are very valuable when a program's goals are clearly and unequivocably given and the corresponding system elements are well defined. It appears to us that no clearly identifiable set of goals exists to guide development of a national transportation system. And the interaction of present and other potential transportation arrangements involves areas which are understood poorly if at all.

We have several demands upon us which must be met if we are to find and follow a wise approach to improving our transportation. First we must adopt a set of goals which recognizes all the roles and potential of transportation facilities and activities. The goals should provide for mobility, in its broad sense, for all our citizens, in contrast to the present situation which caters to those capable of owning and operating a private conveyance. Second, we must extend ourselves as a nation to the task of understanding the interactions of transportation, land use, "quality of life" and the myriad of other human factors.

We need a plan to move us from the jaws of today's problems toward the ideals of tomorrow. We must make positive moves before we have achieved a clear view of where we really want to go. There are a few principles which should be kept in mind. We cannot develop an adequate transportation system by repeating old mistakes. It is evident now that replacing a two-lane, congested road with a four-lane, divided highway usually just moves the problems to new locations. Effective control of demand on particular transportation links will be necessary to alleviate congestion permanently. Transportation facilities should be used as tools for implementing land use plans rather than being developed belatedly in response to demand. Finally, we need utopian ideas of city structure toward which to steer, but any useful plan of action will recognize the tremendous investment in present cities and seek to exploit that which we possess.

"Human factors in transportation systems" necessarily encompass all of these wide ranging considerations, and a design process to hold substantial promise of achieving success, must incorporate appropriate recognition of all such diverse factors.

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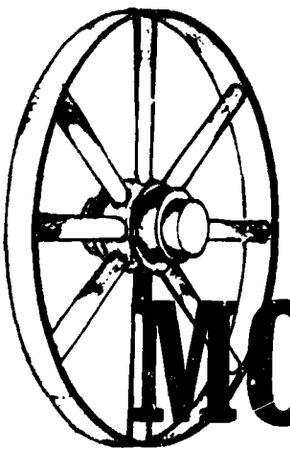

MOBILITY and PEOPLE

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2.0 Introduction

This chapter offers to the reader a description of the most significant characteristics which exist between transportation systems and human beings. The early sections contain general information and briefly describe the essentials of a human factors approach to transportation studies.

The later sections contain more extensive technical aspects concentrating on specific human factors and how certain parameters (such as acceleration, temperature, noise, vibration, etc.) affect comfort and safety in transportation modes. The reader is at this point invited to feast or snack according to the dictates of his background and/or temperament.

2.1 Passenger Transportation In The United States

While this study concentrates on passenger transportation for the most part, human factors in transportation in the broadest view must consider also freight carrying vehicles and transportation systems as they relate to the non-user. Truck and freight train noise is an example of a human factor of paramount importance. Equally important human factors relating to these two example modes (truck and freight train) are (1) the misuse of land caused by large radius turns and low grades on highways strictly for the use of one commercial segment of our society and (2) the esthetic and cultural degradation of river basin lowland areas, because original rail routes utilized these lowlands (relegating potential recreational lands to the category of "along-side of the tracks"). Broadly, this report considers human factors in transportation as human **responses** to transportation-oriented stimuli. Responses of psychological, sociological or physiological nature are of equal concern. This concept is discussed in section 2.2 following, while subsection 2.2.2 specifically identifies categories of stimulus and response in transportation.

This section of the report presents an overview of transportation systems and their intrasystem and intersystem interfaces with emphasis on the stimuli they impose on man.

The primary media for transportation today are, of course, land (highways, and railroads), air, water and pipeline or tunnel; with air cushion or magnetically levitated land systems and V/STOL air systems under development. Air and water systems maintain considerable flexibility in routing, but larger craft for either air or water exhibit considerable inflexibility in interfacing with other systems or in receiving and discharging passengers. This is to say that large airports and harbors are few in number and usually not easy to get to, or to function in once there. Hence the human factors of convenience and time at interfaces are sacrificed for a gain in these same factors during the trip. The length of the trip and the extent of the interface losses tend to counterbalance each other, the result not always being positive. For shorter haul trips this latter fact is especially true. Domestic short-haul waterway systems are limited to specialized circumstances such as ferries. The retirement of many ferries perhaps should be re-evaluated in many coastal and inland watercourses where the substitution of bridges has opened many rural, recreational and aesthetically pleasing areas to automotive congestion and, worse, to land misuse through improper development. Short-haul air commuting requires V/STOL types of aircraft to allow close-in airport location and to minimize trip interface losses. Such aircraft provide considerable route flexibility as they compete with the automobile, which has somewhat less route flexibility, and with the high-speed train, which is quite limited in its routing flexibility. If such human factors as safety, noise, vibration and dollar cost can be improved for the V/STOL types of transportation they will continue to increase their percentage share of passenger miles traveled.

Land-based systems are clearly the most used systems for moving people in the United States. The private automobile heads the list by far. Throughout this report the environmental costs of the automobile are weighed against its extreme interface flexibility and relatively high route flexibility. However, we wish to mention a broader list of land-based systems varying from what might be called pedestrian aids or people movers (elevators, escalators, moving sidewalks), through public automobiles of the taxi (private ride) or dial-a-bus (semi-private ride) types; small vehicle transit systems; buses; trolleys; and high-speed rail systems. Dual-mode systems such as auto-on-train piggyback, highway-track bus concepts, or regular highway-automated highway autos are also under consideration. Pedestrian aids are logically thought of as an extension of the general elevator concept in that they move small

distances quickly and conveniently after the people have arrived at a general destination. Horizontal "elevators," if you will, can serve vital uses in downtown areas, for example, either as an interface between a public transit system and work or shopping place or between a long haul and a short haul transit system. In these cases they induce the traveler not to congest the urban area with his automobile because they add the home-to-office type of flexibility that the long-haul transit alone does not provide. Logical extensions of simple moving sidewalks might include pallet or passenger container systems.

"Public" automobile systems are limited to taxis and rental cars today. In many medium size cities up to half-million persons, dial-a-bus studies indicate that five to eight passengers may be the optimum size of the vehicles. In this case, two- or three-seat autos and vans on the market today can provide demand service. In many cases, local laws relating to public system franchises must be altered.

Buses, an extension of the automobile concept, share many benefits as well as human factor costs with the automobile. Given the highway and residential and commercial land use patterns we now have, the bus is more flexible in pickup, delivery and routing than its predecessor, the tracked trolley. The speed and convenience of buses is greatly enhanced by partially using exclusive rights-of-way. Electric-drive would reduce the noise and air pollution from internal combustion engines, but overhead electric lines are costly and unsightly. The dual-mode rail-bus offers a unique combination of local flexibility and minimal use of land for long haul use. A light rail track uses much less land than would a highway designed for rubber-tired traffic.

Railway systems are, for the most part, long-haul fixed route systems with high initial dollar costs. Some human factor considerations are lack of flexibility in routing and lack of sufficient research to bring them up to even the minimal standards of comfort, cleanliness and on-board convenience. The reversal of this latter trend with the Turbotrain and Metroliner in the Northeast Corridor (where high density travel demand reduces the need for flexibility) has reinstituted interest in the advantages of the railroad.

With the rising costs of urban land and the environmental degradation inherent with surface transportation systems, underground tunnel systems are receiving increased consideration. Automotive tunnels, unless employing automated vehicle control, are probably prohibitive for the near and medium term because of tunneling costs. However, very high speed (up to 500 miles per hour) trains almost completely filling evacuated tunnels offer considerable possibility for high demand areas. A distinct advantage of a subsurface system would be that, with proper planning, undesirable land use in the form of strip development along highways could be avoided. Likewise, the lack of development or the "along-side the tracks" slum development associated with surface rail systems would be avoided.

Walking, bicycling, motorcycling, and trucking are transportation modes which deserve special human factors consideration. Walking and bicycling are extremely flexible modes of transportation, human factors considerations for these modes are obvious. Of special note, however, is the present lack of concern for their interfaces with other modes. Special walkways and bicycle routes could remove much downtown congestion and increase safety measurably. In addition, laws requiring free walking access (principally sidewalks and pedestrian overpasses) would reduce considerably the autophobia of suburbia. Many suburban citizens live within easy access of most everyday needs yet cannot conveniently and safely walk there. More often than not, complete to-the-street land cutoffs such as fences, flower gardens, etc. and divided highways make access to "next door" and "across the street" completely impossible. However, people and bicycles cannot be logically planned for on streets because (1) they do not travel at speeds comparable with motor vehicles and (2) they are not readily visible at all at night and not to the rear and side during the day. Likewise, motorcycles present all of the inconveniences on the highways due to lack of size compatability with autos plus human factor considerations of noise and safety (reported motorcycle deaths are 2500 per year).

Trucks, especially larger ones, are barely compatible with automobiles on the highways, their size and lack of flexibility being largely responsible for this. Much of the criticism of automobiles today is rightfully directed at their conspicuous and polluting aspects. However, the disproportionate dollar and land use costs attributed to the automobile should be attributed to trucks. Highway grades and curvatures are designed for trucks, highway

bridge are designed for trucks, highway subsurface and surfaces are designed for trucks (one legal semi-trailer truck is equivalent to approximately 5000 automobiles for highway surface design). Environmental degradation, capital investment and maintenance, inconvenience, and safety hazards related to trucks are all human factor costs which when divided by societal benefits may provide the highest (worst) ratio of all transportation systems, and many of the alternative modes discussed might make better choices for freight movement.

2.2 Human Factors In Passenger Transportation

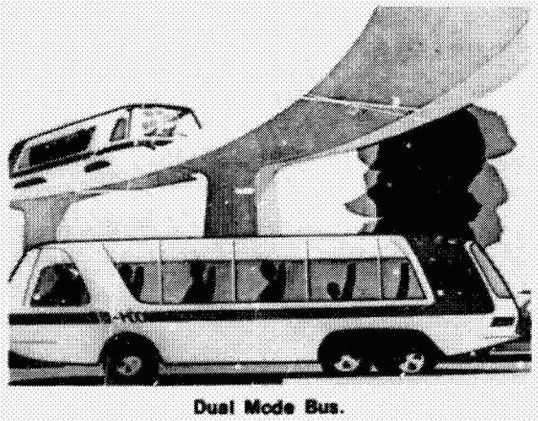
The definition of human factors set forth in Chapter I embraces a broad spectrum of human response, covering all conceivable aspects of how man goes about transporting himself and his goods. In contrast, most earlier studies have taken a characteristically narrow view of human factors, restricting their concern to physiological responses only, or to subjective opinions of vehicle ride quality, or to socio-political community responses. If a proper view of transportation and man's relationship to it is to be taken, as an integrated system, such restrictions must give way to the broader embrace that this study has adopted.

Whether our concern is with old modes of transport with which we are very familiar, or with the emerging new forms that are aimed at erasing the shortcomings of the old, human factors are a very real and very pervasive consideration, for the ultimate measure of a transportation system is how well it supports all the social and economic activities of man. Yet, too often man is forced to conform with transportation systems that are imperfectly designed or improperly operated to meet his travel needs and preferences. To accommodate transportation to man, rather than the reverse, should be the objective and essence of all good transportation design.

Transportation is supplied in many forms, and the demand for it is great and dynamic. The many travel possibilities produce inevitable conflicts and incompatibilities between modes, with consequential distress, confusion and hardship for the traveller. He must thread his way through many, oftentimes

Proposed Los Angeles Vehicle.

Tracked Air Cushion Vehicle.



Dual Mode Bus.

New D. O. T. Turbo Train.

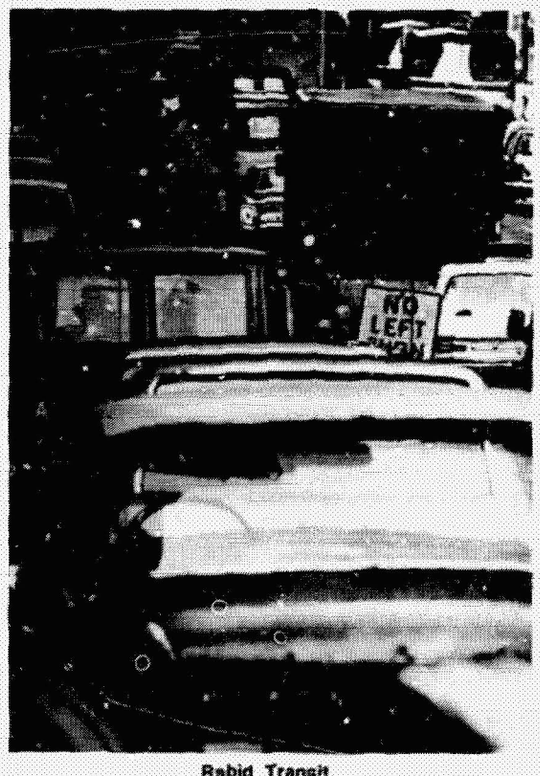
unfamiliar interconnections and must spend an inordinate amount of time in unproductive waiting. Thus, human factors enter into design of transportation to a much greater extent than might be at first anticipated.

When a person can walk across mid-town Manhattan faster than he can drive it, something is wrong. When an urban freeway dislocates residents without compensation or blights the view of a scenic bay, something is wrong. When the time spent in getting to an airport and in waiting for a flight exceeds the time of the flight itself, something is wrong. Exploring the places that transportation does not work well for man often can reveal the ways and means for improvement. The present study, then, while seeming to dwell overly long at times with the wrong side of transportation rather than the tremendous good provided, is motivated by a desire to shed some light on the human side of transportation to the end of enhancing man's comfort, safety, and satisfaction.

2.2.1 Stimulus and Response

The role of human factors in transportation design is suggested by the information flow diagram of Figure 2.1, a main aspect of which is the chain of events from stimulus to response. From the store of knowledge about transportation (inventory), many factors can be identified which somehow impinge on people and stimulate them into making some kind of response. These stimuli, or signals, are received and sensed more or less the same by all people. However, they are perceived and recognized differently among individuals. It is this difference in what people infer from sensations and in how they interpret them, based in part on prior experiences and personal expectations, that accounts for the wide variation of individual response to essentially the same kind of stimuli. One person may be exhilarated and another intimidated by the same crowd on a subway platform. A pilot and his passenger, subjected to the same forces, vibrations and noises of flight, will surely differ in their opinions of ride comfort. Transportation will be judged satisfactory by the extent to which it can accommodate to all degrees of differential response. Thus, an understanding of the stimulus-response chain, and its deliberate incorporation into transportation systems design, are deemed vitally important.

Help!



Rabid Transit.

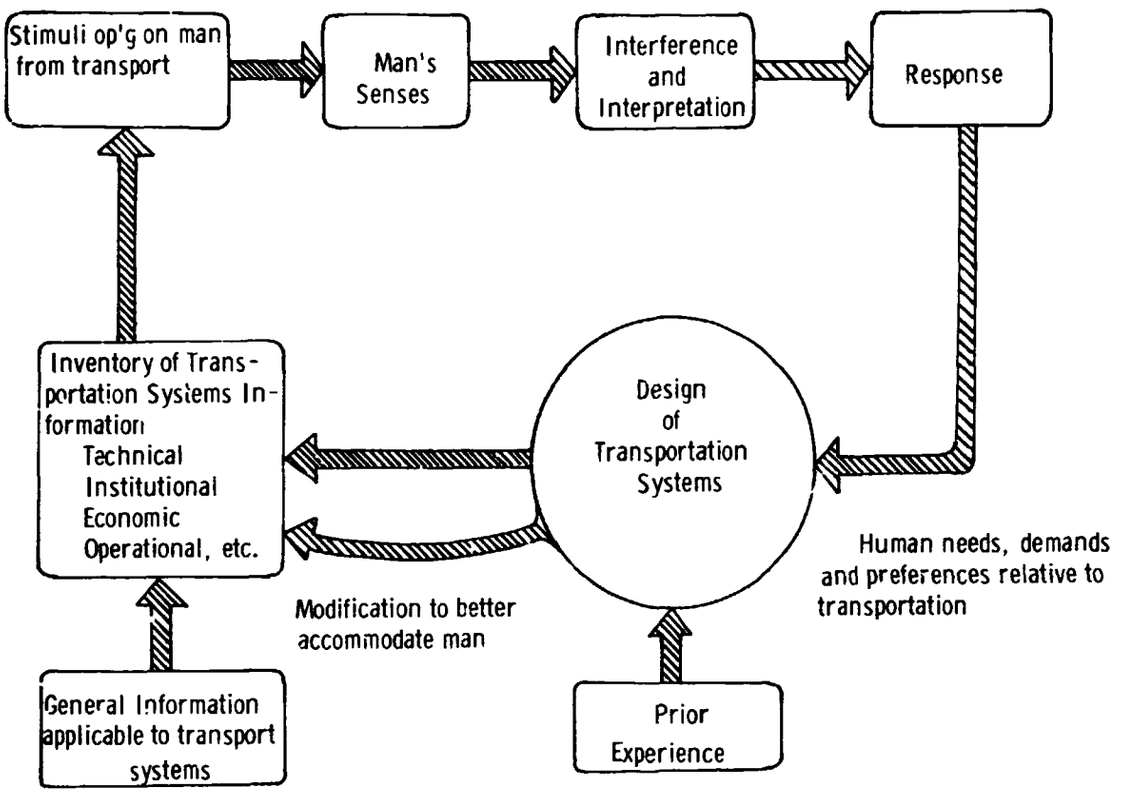


FIGURE 2.1
PRIMARY INFORMATION FLOW IN DESIGN OF TRANSPORT SYSTEMS

2.2.2 Categories of Stimulus And Response

The many possible kinds of response—physiological, sociological, psychological—have been grouped for convenience under the seven categories listed below along with some examples:

Internal Environment

- Speed, acceleration and vibration
- Noise
- Illumination
- Air quality—temperature, humidity, odors
- Space and seating arrangements
- Esthetics—color, cleanliness, eye appeal

External Environment

- Pollution—air, noise, visual
- Congestion and distraction
- Harmony with surroundings
- Preservation of cultural values
- Community stability and orderly growth
- Travel and recreational opportunities

Costs and Benefits

- Direct costs to user
- Disutilities to the non-user
- Revenue and tax structures
- Public financing, subsidies, and capital investment
- Dislocation costs
- Economic growth potential
- Land values and urban growth

Convenience and Mobility

- **Time**—en route, waiting, walking, and parking transfer—intermodal movements, terminals, network connectivity
- **Operation**—availability and frequency of service, schedule reliability, accessibility, arrival/departure compatibility

Information—intelligibility; signs and messages related to routing, schedules, locations, vehicle recognition

Special provisions for disadvantaged persons—young, elderly, invalid and handicapped, transportation-deprived

Safety and Security

Accident risk—real and perceived

Emergency provisions; breakdown recoverability

Impressions of sturdiness and state repair

Crime, real and perceived—lighting, protection, unfamiliar areas, presence of others

Health—atmospheric intoxicants, sanitation

Social Interaction

Desirable and undesirable groupings and confrontations

Freedom to choose travel companions

Personal Space, providing privacy, and crowding

Fulfillment of travel objectives

Reference group opinions

Psychological State

Boredom

Self-esteem

Perceptions of safety and security; alarm and fright

Anxiety and uncertainty, frustration

Sense of personal control

Comfort and quality of ride

Personal expectations

The listing is neither rigid nor exhaustive; rather it is suggestive and intended to provide a framework for later discussion. The given examples are stimuli, for the most part, each associated with responses that can be physiological, sociological, or psychological in nature. Later sections of this chapter treat many of these factors in detail. Some of the factors are seen to be personal issues arising from an individual's interaction with a vehicle or with facilities such as stations and terminals. Others, such as social interactions, are group issues. Still others are community issues which, like air and noise pollution, affect a broad segment of the population, including both users and non-users.

The concept of "group," as used here, is a bit loose. To psychologists, a group is a collection of people banded together purposefully, for an objective that can be satisfied only by member interaction. The key test is whether or not the individual could accomplish his purpose just as well without the group. For example, pushing a car out of a snowbank is a group activity. So is a car pool aimed at reducing travel costs and parking problems for its members. In contrast, people travelling together simply because they are bent on reaching the same destination do not form a group, strictly speaking, because they do not depend on the group for achieving their travel objective. Similarly, public acceptance of a transport mode is not a group response, but rather an aggregation of individual responses. The distinction between groups and aggregates is elusive in many particular cases and it has not seemed useful for the purposes of this Chapter to make a strict differentiation.

2.2.3 Human Factors—Why?

Human factors in transportation design is not a brand new concern. A great deal of research on human factors has been done, in fact, over the last two decades. Much of it, however, has been limited in scope and uneven in coverage and leaves many gaps of knowledge Much of it is general and has not been explicitly applied to transportation. Much more is known, for example, about physiological responses as developed in aviation, space flight, and crash injury research than about psychological responses which relate to man's feelings about transportation. Some of these gaps are likely to be filled, however, in the recent surge of interest in human factors, especially in areas of passenger comfort and behavior-based demand modelling.

The reasons for this increased activity are not entirely clear, at least not in the sense of explicit cause-effect relationships, but it is clear that a number of factors have come into conjunction to account for it. Increased affluence has made private transportation, especially the automobile, within the reach of more people. There is more demand for transportation from an increasingly mobile society, yet the supply of transportation is restricted by the increased cost of private transportation and limited tax resources for public transportation. Inevitably, these things

produce sharper conflicts in the form of congestion and crowding and encroachments on the quality of life. The conflicts and inadequacies are more highly publicized and create greater public awareness and higher expectations which in turn lead to political pressures for more transportation and demand for higher quality transportation. In short, society has asserted its rights to safe, comfortable and pleasant transportation that works efficiently, and its expectation that technological considerations will be subordinate to human needs and desires.

The following sections, therefore, explore in some detail a number of important areas of interaction between man and transportation and suggested related implications for design. Most of these areas pertain to the individual's relation to vehicles and facilities, although group and community issues are treated whenever the technical background makes it natural to do so.

2.3 The Nature and Manifestation Of Human Factors Affecting the Individual

2.3.1 The Motion Environment

A vehicle and its occupants together comprise a physical system that is subjected to forces and vibrations when in motion. The characteristics of motion and the magnitude of its effects are governed by physical laws and no man in motion can escape them. Human response to those effects, the degree to which a person is able or willing to tolerate them, thus has a great deal to do with safety and comfort and with acceptability of a transport mode.

2.3.1.1 Velocity

A constant velocity produces no forces and has no physical effect on people riding in an enclosed vehicle. Sensations of speed, and associated feelings of fright or excitement, depend in that case entirely on visual references external to the vehicle, such as trees or power poles passing by a window, and on noise of mechanical or aerodynamic origin. In an exposed position, a passenger may be subjected also to direct aerodynamic effects such as wind pressure, buffeting, or blowing of hair and clothing. Most vehicles enclose the passenger, so velocity effects, *per se*, are not an important consideration. Even psychological reactions to high speed tend to be positive. That is, once a person is assured of safe operation, he welcomes high speed as an end to saving time, on which he places a high value.

Many effects attributed to speed actually are due to acceleration, the time rate of change of velocity. Crash impact forces, for example, are produced by rapid deceleration from an initial velocity to a stop. Similarly, the constant speed of escalators and moving sidewalks is no problem except as a person must accelerate from a standing position or walking speed in order to mount them. Normal escalator speeds of 90 feet per minute (roughly 1 mph) and a few of 120 feet per second, as used in the United States, seem to present no difficulties; speeds of as much as 180 feet per minute, as for escalators in London subway terminals, are often difficult for physically handicapped and burdened persons to negotiate.

2.3.1.2 Acceleration

In recent years, increasing emphasis has been given to high-speed vehicles with high acceleration and braking performance As the velocity of a vehicle changes, occupants of the vehicle are subjected to forces which cause displacements of head, trunk, and limbs of the body and of internal organs, blood, and tissue. These displacements are sensed by kinesthetic and other receptors to produce in man sensations not only of motion but also of annoyance, discomfort or pain, generally with both physiological and psychological manifestations. To the extent that an occupant's body and its parts can move relative to the vehicle and collide with parts of it, as in the case of crashes, serious injury or death may occur. Moreover, parts of the vehicle or contents may dislodge and strike the body, causing injury. It follows, then, that vehicles and their structural and operating characteristics ought to be designed to prevent or minimize deleterious effects upon man.

Acceleration is taken here to mean isolated or nonrepetitive accelerations sustained for a short period of time, as opposed to the oscillatory accelerations that occur in vibrations. It is commonly stated as a multiple of the acceleration of gravity, g (32.2 ft/sec^2); for example, an acceleration of 320 ft/sec^2 is approximately 10g. This relationship

is the basis of the notion of g-forces; a 10g acceleration, for example, is associated with a 10g force, a force ten times that exerted by gravity, or in the case of a human body, ten times the body weight.

A reactive inertial force, resisting motion and equal and opposite to F, is produced also, and it is this force which acts physiologically on a human body and its parts whenever a vehicle accelerates. Thus, a human subject facing forward and being propelled forward will experience a displacement of internal organs (heart, lungs, etc.) toward the spine, and of the eyes inward. The reactive force divided by the body mass is the physiological acceleration, usually designated as a multiple of G-32.2 ft/sec^2 (G being used to distinguish it from g). The physiological descriptor G is additionally specified in direction according to orthogonal axes related to the human body. By this system, +Gx produces transverse chest-to-back displacement of the heart as a result of forward motion of the body; +Gy is a right-to-left heart displacement resulting from body motion to the right; and +Gz is a head-to-foot displacement resulting from upward body motion. Table 2.1 and Figure 2.2 clarify the relationship between various nomenclatures.

The effects of acceleration on the human organism range widely, from severe, catastrophic disturbances that result in death or serious injury to relatively mild disturbances that produce little, if any, physical and psychological sensation. Broadly speaking, humans can tolerate high acceleration forces for short times, as for example occurs upon impact, or small acceleration forces sustained over a relatively long time. Likewise, the range of accelerations to which humans may be subjected is very wide in terms of variation in direction of applied forces, magnitude, duration, and rates of buildup and decay, as well as the passenger's posture (standing or seated), his seating conditions, and his orientation to applied forces.

Acceleration effects can be grouped into three broad categories, namely:

(a) extreme conditions where the concern is survivability and serious injury, as in vehicle collisions, and the design issue is the safety and protection of occupants;

(b) intermediate conditions where the concern is temporary debilitation and deteriorated task performance and the design issue is reduction of the

TABLE 2.1
EQUIVALENTS FOR ACCELERATION TERMINOLOGY

Equivalents for Acceleration Terminology

	Direction of acceleration		*Physiological reaction*		
Direction of motion	*Aircraft computer standard* (1)	*Acceleration descriptive* (2)	*Physiological computer standard* (3)	*Physiological descriptive* (4)	*Vernacular description* (5)
			Linear motion		
Forward	$+a_x$	Forward	$+G_x$	Transverse (A-P)* G Supine G Chest to back G	Eyeballs in
Backward	$-a_x$	Backward	$-G_x$	Transverse (P-A)* G Prone G Back to chest G	Eyeballs out
Upward	$-a_z$	Headward	$+G_z$	Positive G	Eyeballs down
Downward	$+a_z$	Footward	$-G_z$	Negative G	Eyeballs up
To right	$+a_y$	Right lateral	$+G_y$	Left lateral G	Eyeballs left
To left	$-a_y$	Left lateral	$-G_y$	Right lateral G	Eyeballs right
			Angular motion		
Roll right	$+\dot{p}$	Cartwheel	$-\dot{R}_x$	Roll	
Roll left	$-\dot{p}$	Cartwheel	$+\dot{R}_x$		
Pitch up	$+\dot{q}$	Somersault	$-\dot{R}_y$	Pitch	
Pitch down	$-\dot{q}$	Somersault	$+\dot{R}_y$		
Yaw right	$+\dot{r}$	Pirouette	$+\dot{R}_z$	Yaw	
Yaw left	$-\dot{r}$	Pirouette	$-\dot{R}_z$		

* A-P = anterior-posterior; P-A = posterior-anterior.

Source: McCormick [1] Table 17-1 as adapted from Gell, 1961, *Aerospace Medicine* 32 (12) p. 1109.

potential for accidents due to motion illusions, misjudgment, misreading of signs and signals, and the like;

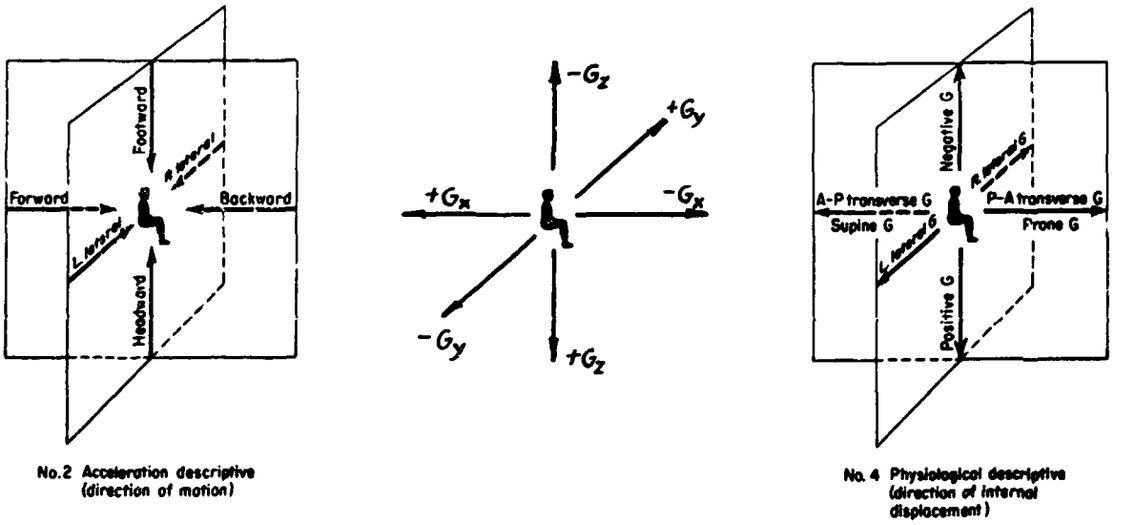
(c) moderate conditions, as in normal transportation service, where the concern is level of annoyance, discomfort, or distress and the design issue is the provision of comfortable ride characteristics, i.e., "ride quality." A succinct overview of such effects is given by McCormick [2.1]. Much of the information available up to 1964 on effects of acceleration and other stimuli is summarized by Webb [2.2].

Only extreme conditions of vehicle collision and moderate conditions relating to ride quality are discussed here. An overview of other aspects is given in Appendix F.

2.3.1.3 Crash Injury

The average rider on transportation systems experiences extreme conditions of impact mainly in the event of collision or rollover of his vehicle. He may be propelled against the inner walls of the passenger compartment or against fixtures such as an adjacent seat or an automobile steering column. He may impale himself on protruding objects and be struck by flying objects, such as broken glass. Head and thoracic injuries are, by far, the leading causes of fatalities. Gross statistics of fatalities occurring on various modes of transport, readily available through publications of the National Safety Council, show that motor vehicle fatalities and injuries greatly exceed, by several orders of magnitude, those for any other mode of transport. It is not at all surprising, then, that nearly all crash injury research has been oriented to motor vehicles, especially the automobile. An impressive amount of research has been done over the past two decades on automobile crash-worthiness (stemming out of earlier work on aircraft crashes), much of it conducted at Cornell Aeronautical Laboratory, Inc., Buffalo, New York, under contract to various Federal agencies, automotive manufacturers, and manufacturer's associations. Some of that research has been summarized by Carter [2.3] with particular reference to tests on passive, impact-deployable air-bag restraint systems and on energy-absorbing structural modifications to vehicles. Technical reports of Cornell Aeronautical Laboratory, among which Reference 4 provides a useful state-of-the-art summary, form the major source of information.

For reasons of dominating importance (the near-exclusiveness of the research



No.2 Acceleration descriptive (direction of motion)

No. 4 Physiological descriptive (direction of internal displacement)

FIGURE 2.2
SCHEMATIC REPRESENTATION OF SELECTED DESCRIPTORS, AS GIVEN IN TABLE I

[Adapted from McCormick, Ref. 2.1]

literature and of rather clear applicability to other modes of transport) the remainder of this section is devoted to automobile crash research.

Some statistics will help to illustrate the nature and gravity of the problem. Recent motor-vehicle fatality figures (1971) given out by the National Highway Traffic Safety Administration show that the approximately 55,000 fatalities per year are distributed as follows:

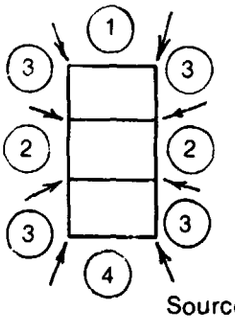
- Occupants of motor vehicles 40,000
- Pedestrians and bicyclists 11,000
- Motorcycle 2,500
- Other 1,500

Of the 40,000 occupant fatalities, 49 percent occurred in head-on collisions, 26 percent side-on, 6 percent rear-end, and 19 percent in rollover accidents. Clearly, the direction of the crash impact force is an important consideration and the predominance of head-on collisions suggests why most auto crash research has been concerned with that type of accident. A slightly different perspective is given in Table 2.2, based on Automotive Crash Injury Research (ACIR) data as reported in Reference 1. These data, covering nearly 25,000 incidents, represent predominantly rural area accidents and only those in which at least one occupant was injured. Frontal collisions were the most frequent, and roll-over the next most frequent. Rollover accidents, taken as a group, were most often severe, followed by side-on impact of the passenger compartment, and these types had the correspondingly higher proportions of injuries and deaths. The dependency of severity and injury on direction of the impact force is well illustrated here. Variation in severity may be attributed not only to the capacity of the various structural areas of the vehicle to absorb crash energy, but also to man's directional tolerance for accelerations. Rollover injuries, for example, must surely reflect the known lower human tolerance for lateral and angular accelerations. Clearly, rollover accidents require much more research, but frontal accidents provide the greatest potential for reducing the actual number of injuries and fatalities.

The frequency of passenger ejection under side-on impact and rollover suggests that ejection can be reduced by impact-proof door

TABLE 2.2
ACCIDENT TYPE COMPARISONS

Accident Type	Number and percent	Severe or extremely severe accidents,* percent	Dangerous or fatal injuries, percent		Ejection percent	
			Driver	Rt. Ft. Pass.	Driver	Rt. Ft. Pass.
HO	14541 (59 1)	9.5	9.6	9.7	3.7	4.3
SO-2	2257 (9.2)	30.0	18.3	18.9	17.7	19.2
SO-3	1009 (4.1)	7.0	11.1	10.4	19.5	20.3
RE	1700 (6.9)	4.5	1.9	2.8	2.0	2.0
RO-NC	2906 (11.8)	17.8	15.7	13.0	29.8	27.1
RO-BC	241 (1.0)	31.1	20.6	14.5	33.1	30.0
RO-AC	1938 (7.9)	29.8	18.1	15.5	29.6	30.2



Region	Symbol	Accident Type
1	HO	Head-on (11 to 1 o'clock)
2	SO-2	Side-on, passenger compartment (2 to 4 o'clock)
3	SO-3	Side-on, non-compartment (e.g., fenders)
4	RE	Rear end (5 to 7 o'clock)
	RO-NC	Rollover—no collision
	RO-BC	Rollover—before collision
	RO-AC	Rollover—after collision

Source: [4]

*Based on extent of damage judged from photographs

latching and by passenger restraints. However, motorists have been typically reluctant to use restraining harneses (either lap-belt or over-the-shoulder type), even when installed in the vehicle, and this has provided much of the current impetus toward requiring installation of passive restraint systems and harness-ignition interlock systems on automobiles.

Better protection against head-on impact decelerations could be provided by rearward-facing seats because they can absorb impact energy and because humans have somewhat greater tolerance to +Gx accelerations. While rearward-facing seats are entirely feasible for most passenger vehicles, such as trains and aircraft, they are most unlikely to be acceptable to automobile passengers who are completely adapted to forward-facing seats.

In much of the crash injury literature, there is a pervasive implication that the energy absorbed through crushing of the vehicle structure, which often collapses by as much as three feet, will reduce the impact forces on the occupant. The occupant, however, undergoes the same velocity change as the vehicle, but benefits only from the much smaller collapse of whatever interior structure he happens to strike, perhaps only 2 or 3 inches, and suffers correspondingly larger impact forces. To avoid these higher forces, and to take advantage of vehicle crushability, the occupant must be constrained by a suitable harness to decelerate with the vehicle. Alternatively, the pillowing effect of an air-bag constraint system provides similar protection. With suitable harnesses, crash forces of 20G are potentially survivable. The NHTSA has estimated that forces as large as 60G may be survivable with air-bag restraint.

2.3.1.4 Pedestrian-Vehicle Impact

But what of the pedestrian who is struck by a vehicle? Pedestrian fatalities, currently about 10,000 per year, pose a serious problem. Twenty-five percent of all fatalities are elderly persons with impaired vision, coordination, or judgment. Eighty-five percent of all pedestrians involved in traffic accidents are children 5 to 14 years old. Sixty percent of pedestrian accidents occur in urban-suburban residential areas. Yet, little research has been done, unless collection of fatality statistics can be so regarded. The National Highway Traffic Safety Administration, in spite of abiding concern for the pedestrian accident problem, has devoted relatively feeble effort thus far to its solution, most of its studies being oriented toward vehicle modifications that could lead to attenuation of pedestrian injuries. The problem is admittedly difficult. Initial impact injuries can be reduced by removing sharp corners and penetrating protrusions from the vehicle and by providing energy absorbing front-end structure (which may be in conflict with requirements to protect the vehicle occupant), but little else beyond this suggest itself. Studies suggest that secondary impact with the roadway, commonly by the head, may contribute more to pedestrian injury than the initial impact. In that case the researcher must be content with studying human trajectories of a complex sort and possibly inventing people-catching devices, such as an impact-deployed net, to clasp the pedestrian victim to the vehicle. It may be, therefore, that substantial attenuation of pedestrian injuries by direct means is impossible, practically speaking, and that protection can be provided best by indirect means, such as complete grade separation of vehicle and pedestrian movements.

2.3.1.5 Ride Comfort

Except in the case of vehicle collision, the average user of transportation never experiences accelerations at extreme levels. Rather, he is subjected to accelerations at much lower levels at which little, if any, physical and psychological damage occurs and at which his main response is related to ride comfort or "ride quality." That is not to say that the rider may not experience distress, or even suffer injury if thrown off balance by unexpected forces. For the most part, however, his response is subjective and is expressed in such terms as fright, annoyance, tolerable discomfort, and comfort.

Magnitudes of accelerations associated with various modes are collected in Table 2.3. The duration of the acceleration has been reported in only a few cases, but with the exception of lateral accelerations during turning maneuvers, it likely does not exceed a few seconds in any instance.

How often these accelerations occur during the course of a trip is surely an important element of subjective response. For instance, an acceleration occurring infrequently, as in emergency braking, may be rated acceptable, whereas the same magnitude of acceleration experienced often

TABLE 2.3
MAGNITUDE OF ACCELERATION EXPOSURE ON VARIOUS TRANSPORT MODES

Mode and Condition	Acceleration, g / duration, secs.			Jerk	Reference
	Longitudinal	Lateral	Vertical	g/sec.	(page or ...)
Elevators,					
average "fast service"			.1- .2/1-5		[illegible]
comfort limit			.3		[illegible]
emergency deceleration			2.5		[illegible]
Automobiles,					
comfortable normal stop	.25/[illegible]				[illegible]
very undesirable stop	.45/3-5				[illegible]
crash (survivable)	[illegible]				[illegible]
normal start	.25/[illegible]				
"racing" start to 5 mph	.7/4 to .9/3				calculated
maximum obtainable stop	0.4/3 to .92/[illegible]				[illegible]
passing, 2mph initial to 35mph final	.[illegible]/9				[illegible]
Motorcycles,					
emergency braking	.[illegible]5- .92/3				[illegible]
passing, 2 mph initial to 35mph final	.13/5				[illegible]
Trains, conventional suburban & intercity,					
Swiss Rapid Transit, starting, normal	.9				[illegible]
, service braking	.75				[illegible]
Penn Central commuter, starting, normal	[illegible]3				[illegible]
, service braking	.13				23
, emergency braking	.113				23
Trains, advanced, high-speed, inter-city,					
"Metroliner", Northeast Corridor, service braking from [illegible] mph	.57				[illegible]
service braking below [illegible] mph	.[illegible]6				[illegible]
curve @ 11 mph		[illegible].5/16			[illegible], Fig. 4 a
curve @ 1[illegible] mph, projected design vel.		.22/1[illegible]			a [illegible]/r
Japanese New Tokaido Line, service braking, below 7 mph	.7				[illegible]
, 7 -1.0mph	.5				[illegible]
, [illegible] -155mph	[illegible].4				[illegible]
, emergency braking, below 7 mph	1.2				.3
, 7 -1[illegible] mph	.74				[illegible]
, [illegible] -155mph	.57				[illegible]
Subways,					
Frankfurt , start	.14[illegible]				[illegible]
, service braking	.17[illegible]				[illegible]
, emergency braking	.3[illegible]				[illegible]
Montreal Rapid Transit, start	.113				[illegible]
, service braking	.113				[illegible]
, emergency braking	.13[illegible]				[illegible]
London Underground , start	.16				[illegible]
, service braking	.1[illegible]				[illegible]
, emergency braking	[illegible]9			.45	[illegible]
Manchester Metro , start	.16				[illegible]
, service braking	[illegible].11				[illegible]
, emergency braking	.16			.14	[illegible]
Munich , start	.1[illegible]2				[illegible]
, service braking	.1[illegible]2				[illegible]
, emergency braking	.143				[illegible]
Aircraft, CTOL,					
Landing impact, sink rate ~6 ft/sec (discomfort)	.4/ .5				[illegible]
, sink rate ~4 ft/sec (typical)	[illegible].3/ .5				[illegible]
Ordinary take-off	[illegible].5/ 1				[illegible]
Crash landing (potentially survivable)	?				[illegible]
Boeing 727, take-off	[illegible].3/ [illegible]	.11	.1		24, Fig. 9
, landing	0.5/ 10	.125	.33		24, Fig. 9
Aircraft, V/STOL					
Breguet 941 (STOL), take- off		.[illegible]0	17		24, Fig. 9
, landing		[illegible].10	35		24, Fig. 9
Ships, Air-Cushion Vehicle (hovering craft)					
Impact, at bow, encounter with isolated wave pattern, 4-5 ft. waves			3.0		
Impact in rough sea , typical	.2- .[illegible]				[illegible]
, maximum	1.2				[illegible]
Ditching at 5[illegible] knots, emergency stop or all-engine failure		[illegible].5	1.0typ 1.5max		[illegible]
Turn, 45 knots, 145[illegible] ft radius (normal performance)		.12			[illegible] calculated

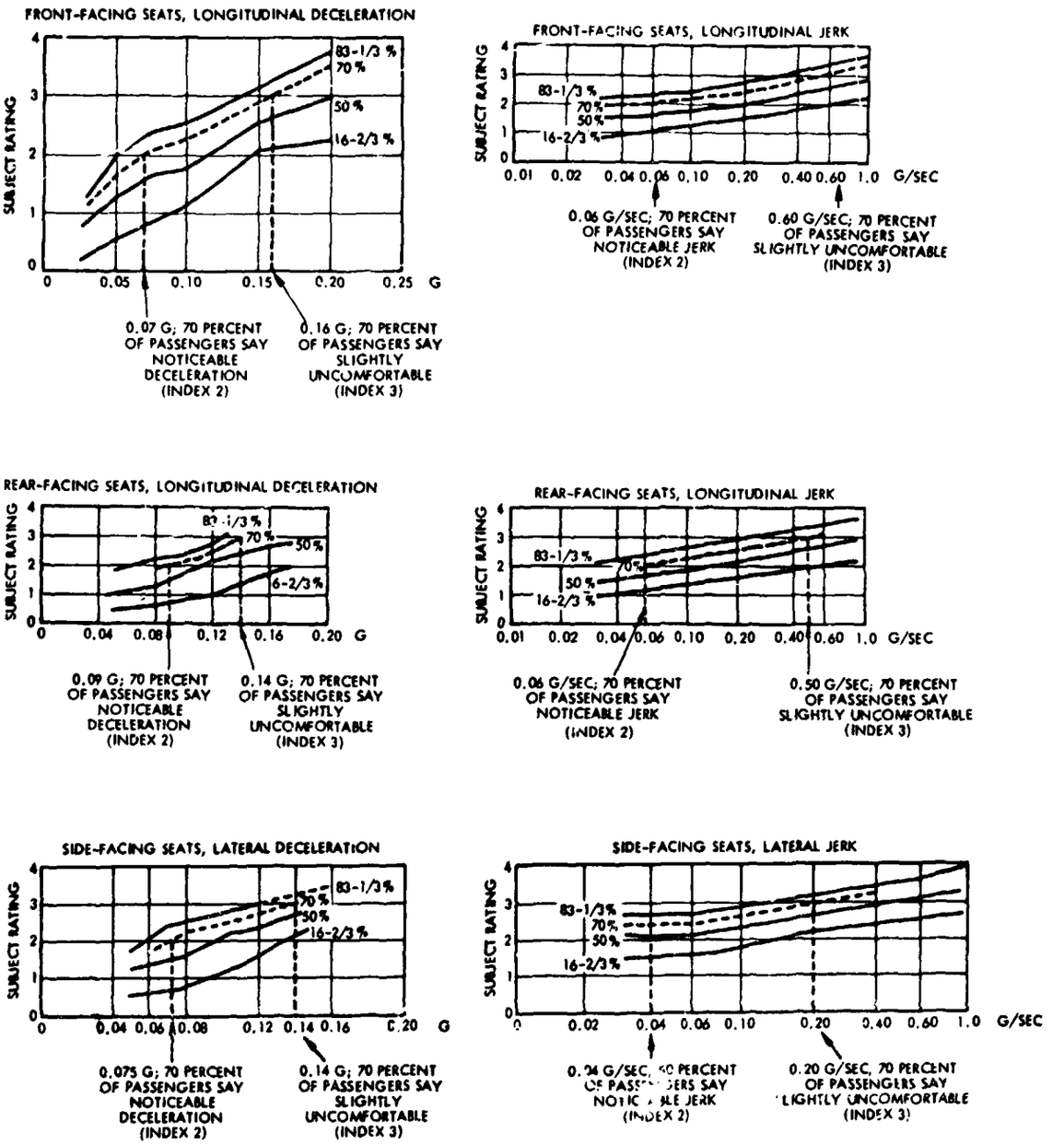


FIGURE 2.3
SUMMARY OF RESULTS OF JAPANESE NATIONAL RAILWAYS STUDIES OF RAIL PASSENGER COMFORT

Source: [Figures 5.4-1,2,3, TRW 2.13]

Rating Scale
0—*not perceptible*
1—just perceptible
2—noticeable
3—slightly uncomfortable
4—quite uncomfortable

during a trip is certain to be rated highly unacceptable. However, little directly helpful information on this matter appears in the technical literature.

Virtually the only information on subjective response to moderate accelerations is found in the research by the Japanese National Railways during the early sixties in connection with ride-comfort standards for the New Tokaido Line, a high-speed rail system [5 through 11]. Carstens and Kresge [12] and TRW Systems Group [13] have given extended summaries of this work that are ample for a general understanding of the subject. Similar information for transport modes other than railroads does not seem to be available. Thus, designers of transport systems must rely heavily on judgment, supported mainly by the JNR results.

The JNR studies, covering only longitudinal and lateral acceleration, asked seated passengers facing frontward, rearward, and sideward (without restraining devices) to state their reactions to a variety of automatically controlled brakings, according to the following five-step rating scale:

0—not perceptible
1—just perceptible
2—noticeable
3—slightly uncomfortable
4—quite uncomfortable

Typical results, deriving from Reference 6 and based on about 7000 individual data, are summarized in Figure 2.3. On the graph for "front-facing seats-longitudinal deceleration" (+Gx), for example, the 50 percent curve represents the level, for any given deceleration, at which half the subjects thought the deceleration was at least as comfortable as that level, i.e. represents the median of all the responses. The upper and lower curves each correspond to one standard deviation from the man, presumably based on a normal distribution. For example, 83 percent of the subjects rates 0.05g as level 2 (noticeable) and 0.14g as level 3 (slightly uncomfortable). Other graphs may be interpreted similarly. Later investigations by Urabe and Nomura [9] and Urabe, Koyma, and Irvase [11] have extended and confirmed the above results.

The main purpose of research of the kind cited above, is of course, to establish criteria for the design of vehicles and systems that will meet acceptable standards of passenger comfort and safety, in this case with respect to acceleration exposures. Figure 2.3, for example, may be used to illustrate how such criteria could be arrived at. Say arbitrarily that at least 70 percent of the passengers should be "comfortable" at level 2 (noticeable) under normal service conditions, and at level 3 (slightly comfortable) under emergency conditions. The corresponding acceleration limits, then, occur at the intersections of the 70 percent curve with the horizontal lines through levels 2 and 3, and are observed to be the following:

		Normal	Emergency
Front-facing, longitudinal deceleration (-Gx),	g	0.07	0.16
Rear-facing, longitudinal deceleration (+Gx),	g	0.09	0.14
Side-facing, lateral deceleration (+Gy),	g	0.075	0.14
Front-facing, longitudinal jerk,	g/sec	0.06	0.60
Rear-facing, longitudinal jerk,	g/sec	0.06	0.50
Side-facing, lateral jerk	g/sec	0.04	0.20

Had the baseline for comfort been set to satisfy, say, 90 percent of the passengers the acceleration limits would have been correspondingly lower. Further implications of this approach and recommended value for various types of proposed high-speed ground systems are given in Appendix F

Limitations on maximum acceleration will always force some trade-off between acceleration, velocity and time since ideal operating conditions are generally not realizable all of the time. Some of these trade-offs are suggested here. Longitudinal acceleration and deceleration will affect, especially for tracked vehicles, the block time between stations and the relationship between vehicle headway and station dwell time. Emergency braking will govern minimum headway between vehicles and have an important influence on automatic control systems. Emergency braking limits may be exceeded under conditions of complete propulsion power failure at high cruise velocities, but the probability of occurrence should be quite low and the deceleration loads well within limits of human tolerance, even if uncomfortable. Lateral acceleration will occur whenever the vehicle heading changes and will affect switch geometry, minimum radius and superelevation of curves, and geometry of spiral transitions When lateral acceleration limits cannot be met on excessively sharp curves or bank angles, reduced operating speeds and active (as opposed to conventional passive) suspension systems may be required. Vehicle limits will affect mainly the rate of vehicle curvature of the route, but this is not likely to be a serious consideration. Finally, route locations should be selected so as to avoid too many directional changes close together, since passengers will be discomforted by frequently occurring low-level accelerations.

2.3.1.6 Illusions and Disorientation

The foregoing discussion of subjective response to acceleration has been oriented primarily to the passenger. An operator of a transport vehicle reacts in a similar manner, although greater familiarity with the vehicle, better ability to anticipate vehicle movements, and perhaps a different set of expectations of what the acceleration environment should be, all tend to make him less severe in his judgments of riding comfort than the average passenger. He may undergo, however, some acceleration effects that are important for him, particularly in terms of task performance, but relatively unimportant for passengers These effects are chiefly motion illusions thought to arise from conflicting or incomplete signals to his sensory organs, such that the sensory cues are misleading and result in perceptual and judgmental errors. McCormick [1] discusses disorientation of airplane pilots resulting from acceleration and angular changes in direction that leads to gross underestimation of angle of banking and major errors in judgment of turns and recovery from turns. Impressions of being tilted when flying level and vice versa, especially when there is no external visual reference (as in fog, darkness, etc.), can cause serious misjudgments. Also reported is a study of forward-facing airplane occupants who sensed a backward tilt (climb) under forward acceleration and forward tilt (dive) under forward acceleration when, in fact, the airplane was flying straight and level. Pilots, when decelerating for a landing under conditions of poor visibility, thus may receive an impression of descending too rapidly and, in correcting for it, overshoot the runway. This possibility emphasizes the need for reliable and unambiguous airport lighting, especially when ground glare and surrounding lights in the vicinity could cause confusion.

McCormick also cites studies in which automobile operators consistently misjudged the instant at which a lead car changed its velocity, the moreso as the inter-vehicular distance increased; others seriously underestimated the time necessary to pass and clear a lead car when another car approached in the opposite lane. Such psychophysical responses, even though they are not caused directly by acceleration forces, are nevertheless important human factors in transportation.

2.3.1.7 Vibration

Vibration is an oscillatory motion in which the acceleration reverses direction frequently. Therefore, many of the characteristics of acceleration previously discussed will apply here and need not be repeated. In particular, the direction of vibrational acceleration can be defined by the coordinate frame of Figure 2.2. Vibrations of various components of transportation systems are transmitted principally through mechanical contacts, although some elements may be acoustically coupled. They can generate noise, contribute to the passenger's discom-

fort, damage vehicles and structures, and injure passengers

Pure (i.e., regular) sinusoidal motions at single frequencies are shown in Figure 2.4. In practice, vibration is very often randomly irregular, as shown in the representative vibration histories of Figure 2.5, and may be thought of as comprising a combination of pure sinusoidal vibrations with different amplitudes and frequencies. In order to deal quantitatively with complex vibration a measure known as "power spectral density" is commonly used The power spectral density, an example of which is shown in Figure 2.6, describes the weighting of the amplitude with frequency of the component motions contained in the complex vibrations. The response of mechanical systems, as well as the human body, to mechanical forces is a strong function of the frequency of the input. Typically a system will possess a set of discrete characteristic frequencies. It will respond most vigorously to inputs which have substantial spectral components near those characteristic frequencies. The characteristic frequencies of the human body in response to various mechanical inputs and the frequency characteristics of motion in various transportation vehicles are therefore of major importance.

Human beings are sensitive to vibrations of frequencies from near zero to 100 000 Hz or more [40] depending on the nature of the application. In contrast with sound, for which the ear is the only receptor of significance, vibrations are sensed by many physical receptors, each having its characteristic frequency range. Sensations of vibration are interpreted as pleasant or unpleasant just as sound may be music or noise. The motion of a boat in a choppy sea or an airplane in rough air causes many people great discomfort and the operation of a chain saw or a rivet gun may be unpleasant to and even injure the hands. Typical vibration effects and their ranges are summarized in Figure 2.7.

Considerable research has been conducted with the aim of determining the effect of vibration on objective measures of performance such as tracking ability, visual acuity, computational ability, etc A review of this work is given by Grether [45]. In summary, it appears that tasks which depend on the central throught processes are little affected by vibrations at levels below the physiological limit. Reaction time and perceptual judgment are not affected by vibration. However, visual acuity is decreased significantly by vibration levels which are otherwise tolerable for considerable periods of time. A review of some of the research on human response to vibration is given in Appendix F. An excellent summary appears in Webb [2] .

Trains, cars, buses, boats, planes, and so on, each have characteristic ride qualities. The vibrational influence on ride quality depends on the dynamic properties of the vehicle and its supporting medium. For any given type of vehicle, the frequency and amplitude can be changed drastically by changes in suspension parameters or in the support characteristics (e.g . rough roads or smooth roads). In addition to these influences, internal machinery in a poorly designed or ill-maintained vehicle can contribute significantly to the vibration environment. A common example is the automobile with an unbalanced wheel.

Figure 2.8 shows the frequency ranges of the principal vibration inputs to passengers in various vehicles and the origins of principal inputs. Figure 2.9 indicates the levels and characteristic frequencies of vibration in typical cases. The frequency range corresponding to significant accelerations in most vehicles seems to extend from about 0.1 Hz to 50 Hz.

Ultimately, the transportation designer requires some criteria or standards against which to design and to judge the performance of transportation components such as vehicles and tracks. The International Organization for Standardization [46] is putting forward a standard on vibration exposure, covering a range of 1 Hz to 100 Hz, which is based on limits of fatigue-decreased performance due to exposure for various time periods. The basic ISO standards are given by Figures 2.10 and 2.11. These limits are to be weighted by appropriate factors for specific applications such as estimation of ride comfort. Ashely [42] discusses the application of the standard to various cases.

Vibrations of frequencies below 1 Hz can lead to motion sickness. Operators and designers of marine vehicles are particularly concerned with effects of such low frequency vibrations. A chart of estimated passenger comfort boundaries for low frequency oscillations is given by Gornstein, Shultz, and Stair [43] and reproduced here as Figure 2.12. The boundaries are indicated for vertical motion only. There is no corresponding data

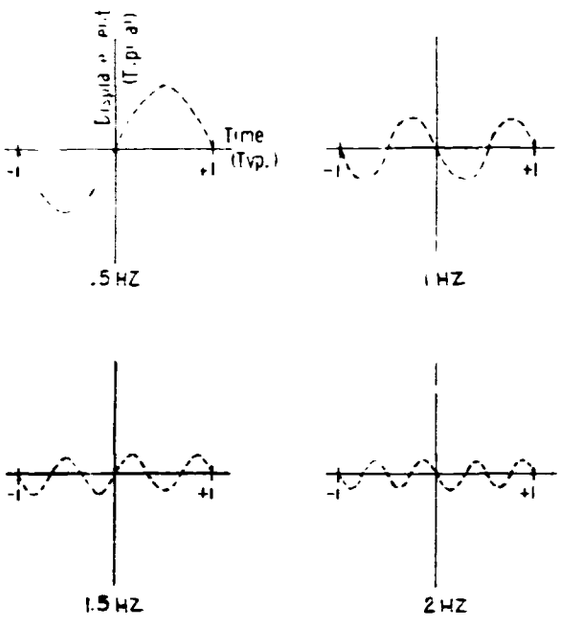


FIGURE 2.4
TYPICAL SEAT MOTIONS IN LABORATORY TESTS
(SINUSOIDAL RECORDS AT SEVERAL FREQUENCIES)

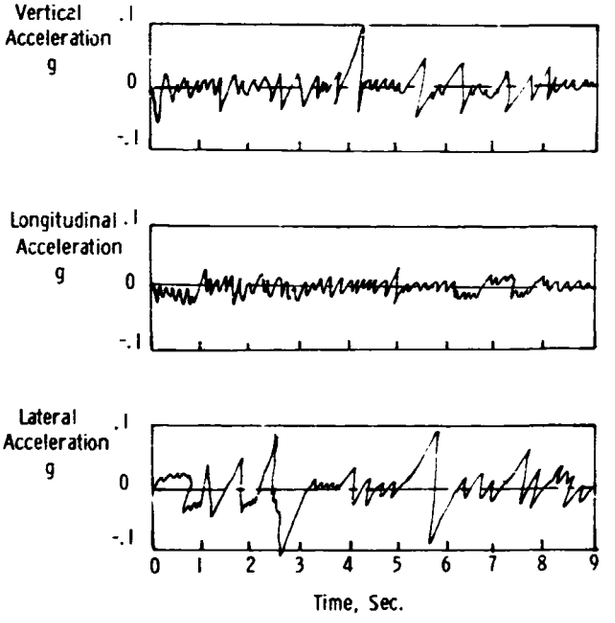


FIGURE 2.5
MOTION OF METROLINER OVER REPRESENTATIVE TRACK SECTION
Source: [29]

in this frequency range for combined vibrations, although Seckel and Miller [44] have found roll rate and yaw rate, as well as vertical acceleration, to be important contributors to passenger discomfort during the flight of aircraft through turbulence

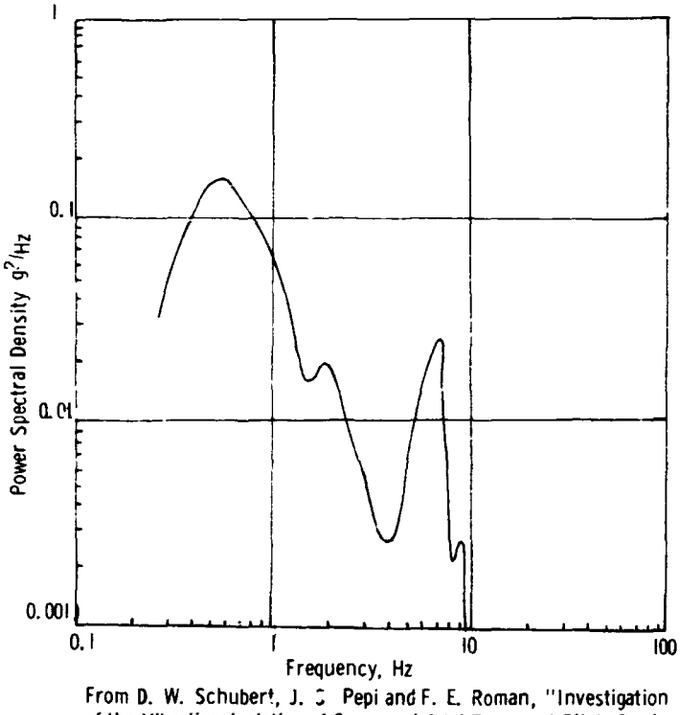
Vehicles can cause vibrations to be transmitted through the earth which in some instances can adversely affect nearby structures and people. There is very little objective data on the effect of transportation-induced building vibration and the subsequent annoyance of inhabitants. The ISO, however, has proposed a standard for vibration exposure in buildings, reproduced in Figure 2..3. It appears that there is a need for research into the factors determining human response to vibrations of low intensity of the kind which can be induced in buildings by traffic or industrial operations.

2.3.2 The Internal Activity Environment

The environmental conditions within closed spaces of vehicles, stations, and terminal buildings have an important influence on the level of satisfaction with transportation and an important bearing on mode choice. Vehicle noise may interfere with speech and the ability to perform tasks such as reading and writing. Concentrations of odors, tobacco smoke, and atmospheric intoxicants, such as carbon monoxide, as well as excessive temperature and humidity, can radically affect comfort and health. Illumination, seating arrangements and space, sanitation, cleanliness, and general appearance, as they are bad or good, will repel or attract people and therefore must be considered in transportation design. These and related human factors are reviewed in the following paragraphs and again it will be found that they have both physiological and psychological dimensions.

2.3.2.1 Noise

Noise is defined as unwanted sound. It can cause temporary and permanent injury, interefere with speech communication, mask signals and messages, distract and annoy; noise is an inevitable by-product of transportation. A review of transportation noise



From D. W. Schubert, J. J. Pepi and F. E. Roman, "Investigation of the Vibration Isolation of Commercial Jet Transport Pilots During Turbulent Air Penetration" NASA CR-1560, July 1970.

FIGURE 2.6
POWER SPECTRAL DENSITY FOR AIRCRAFT MOTION DURING FLIGHT IN TURBULENT AIR

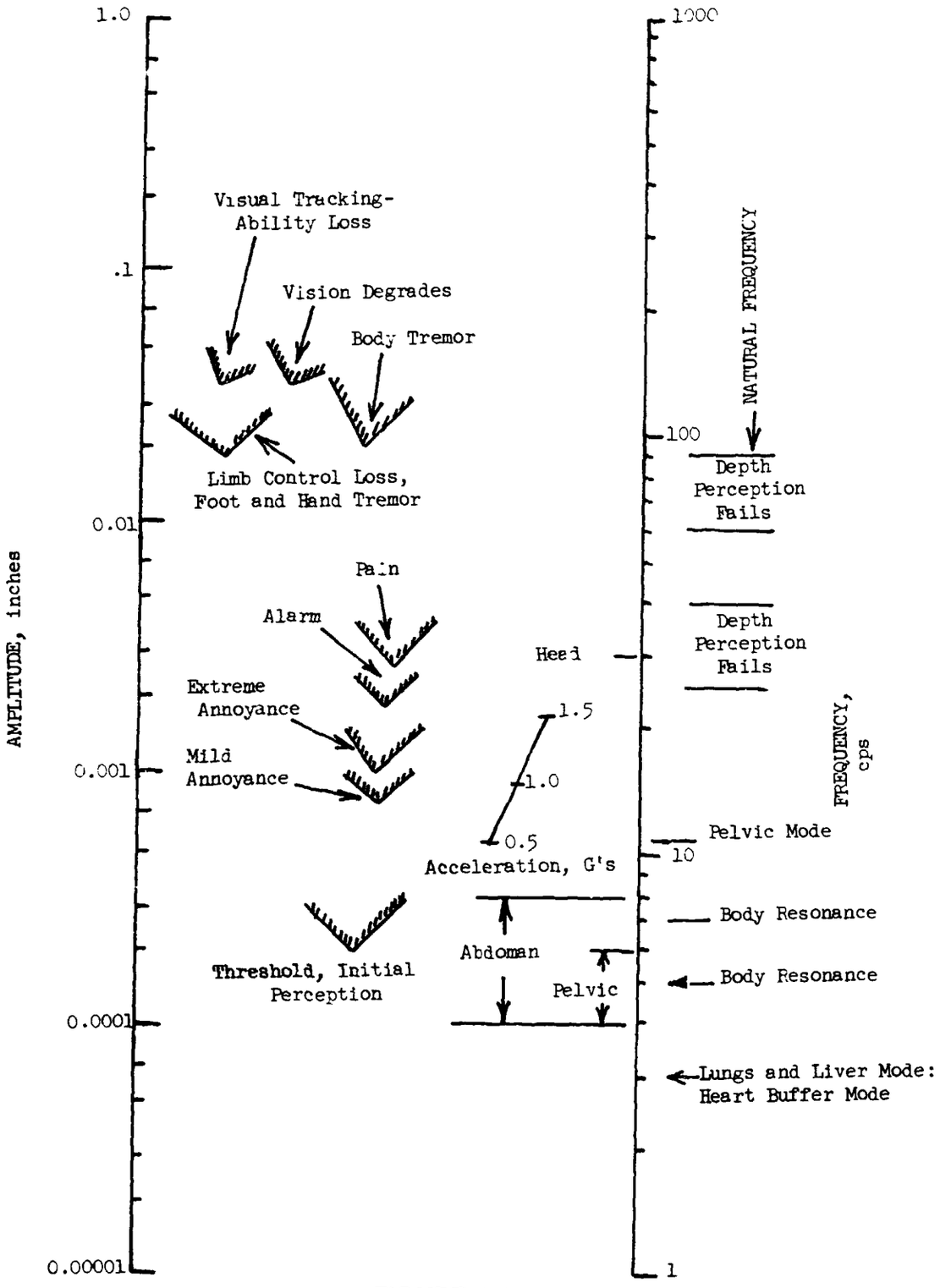


FIGURE 2.7
EFFECTS OF VIBRATION ON HUMANS

Source: [40]

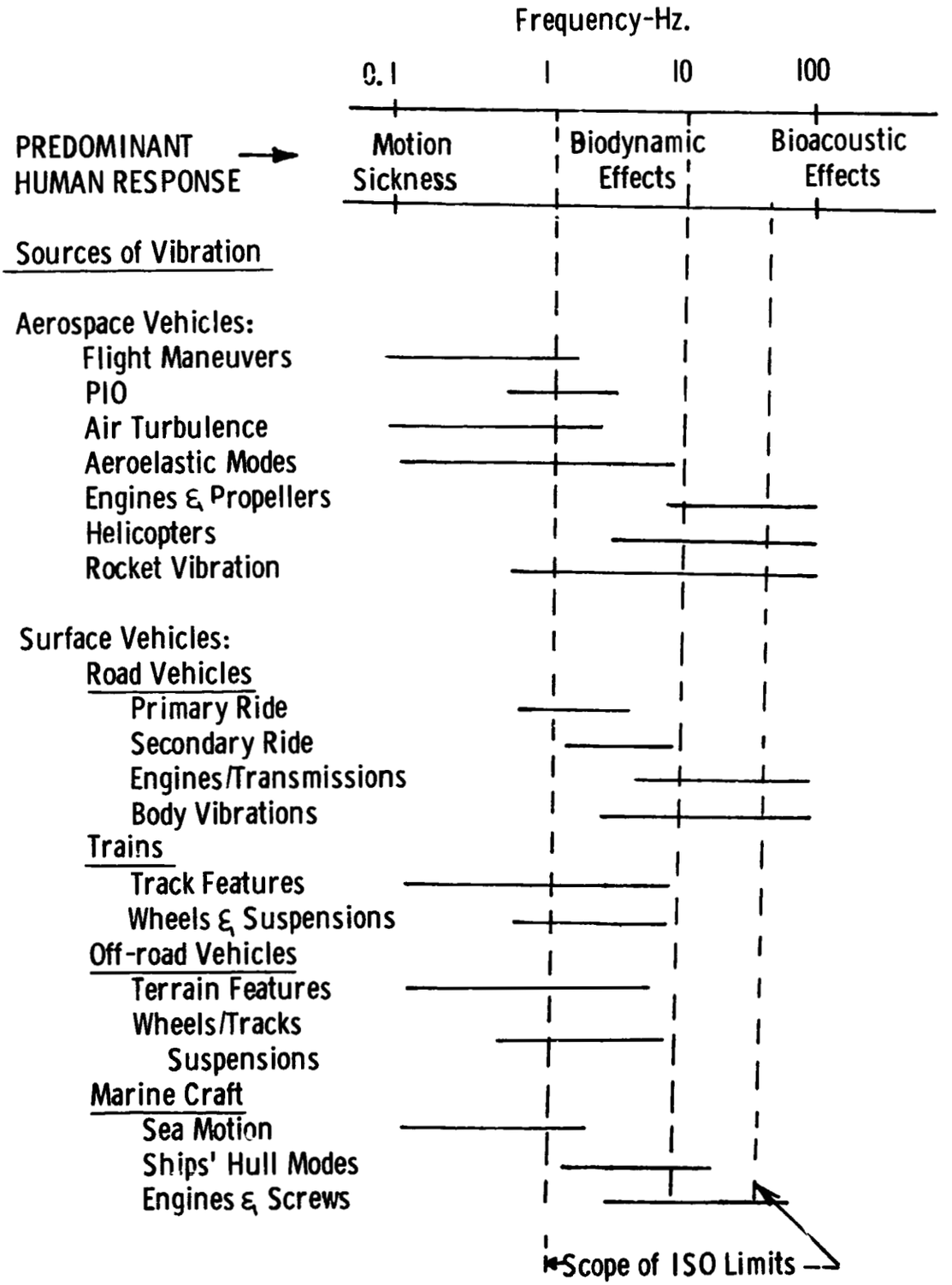


FIGURE 2.8
FREQUENCY RANGES OF PRINCIPAL SOURCES OF VEHICLE VIBRATION
Source: [14]

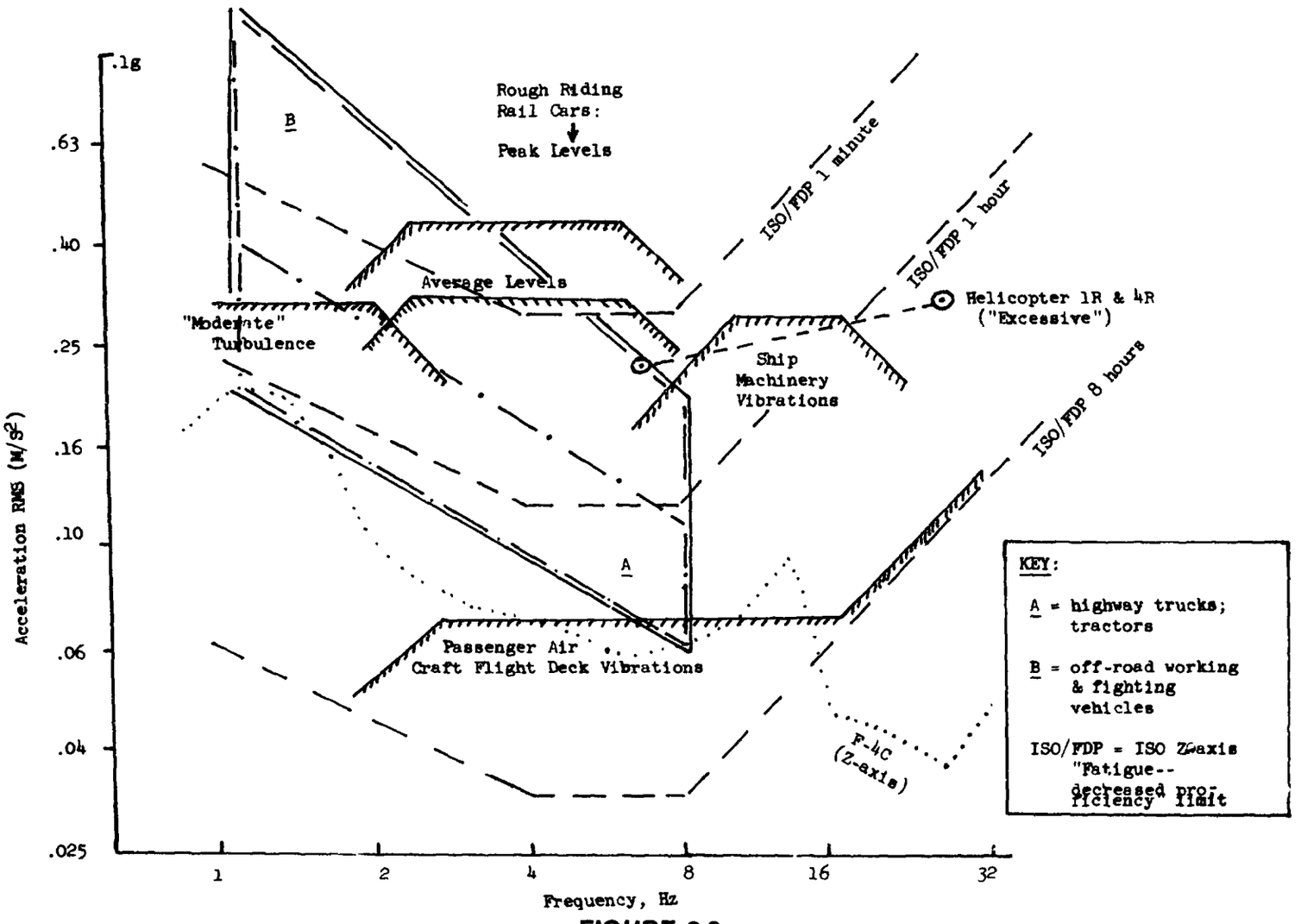


FIGURE 2.9
VIBRATION LEVELS IN TRANSPORTATION VEHICLES

Source: [14]

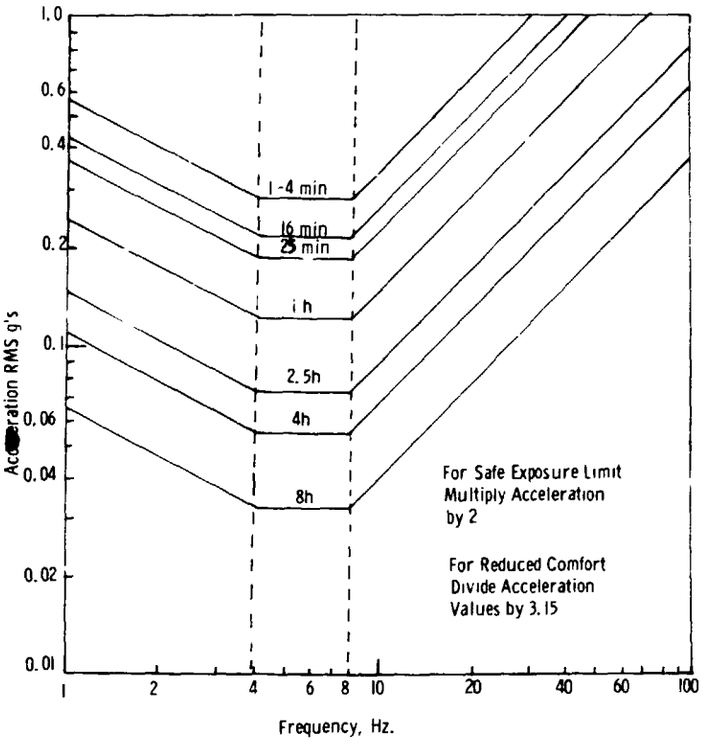


FIGURE 2.10
ISO RECOMMENDATIONS FOR VERTICAL VIBRATION EXPOSURE LIMITS (FATIGUE DECREASES PROFICIENCY BOUNDARIES)
Source: [42]

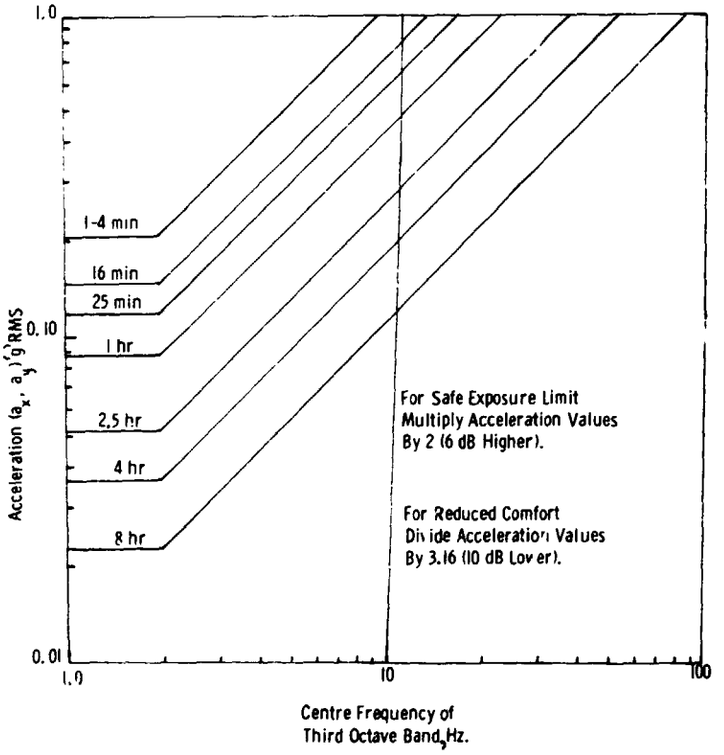


FIGURE 2.11
ISO RECOMMENDATIONS FOR HORIZONTAL (Ax, Ay) VIBRATION EXPOSURE LIMITS
Source: [42]

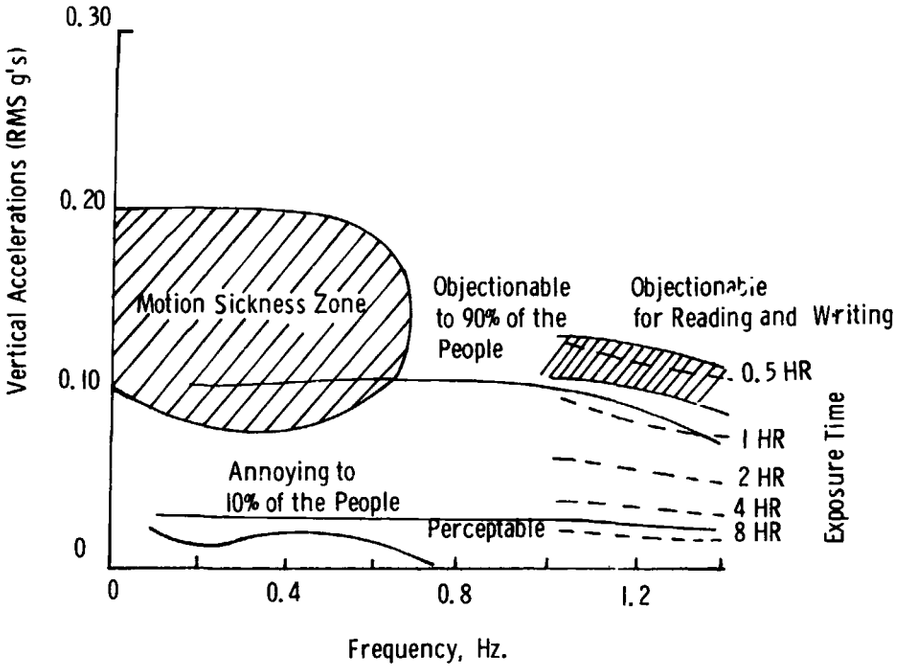


FIGURE 2.12
TENTATIVE PASSENGER COMFORT BOUNDARIES

Source: [14]

follows, including some basic facts about sound generation and measurement, but it is necessarily brief in view of the many substantial and detailed aspects. The reader is referred to several excellent summaries [53, 54, 55] for additional elucidation.

Sound is propagated as a pressure wave through the air. At a particular point, being subjected to sound waves, say at a human ear, the pressure will oscillate slightly above and below the ambient atmospheric pressure. This pressure variation will cause any surface which may be present, such as an eardrum, to oscillate in response to the varying force applied to it. Different surfaces will respond to a given pressure variation in various ways depending on how stiff, resilient, or massive they may be.

Conversely a surface such as a drum head or the side of an engine block, when caused to vibrate by mechanical forces, will cause pressure variations in the surrounding air and give rise to sound waves whose amplitudes and frequencies will depend on the vibrational motion of the mechanical surfaces. Oscillating pressures may also be generated within a flowing gas if it is turbulent, as is usually the case for flow in the exhaust pipe of an automobile or for flow around a truck trailer moving at highway speed.

A sound is characterized by its amplitude and frequency content. The amplitude of sound is usually stated in terms of a decibel (db) scale which is 20 times the logarithm (base 10) of the ratio between the root-mean-square (rms) pressure and a reference pressure. The accepted reference pressure for acoustic work is 2 X 10-10 dynes per square centimeter (.0002 microbars). This is considered the threshold of hearing at the frequencies most easily detected by the human ear. This unit of measurement causes a good deal of trouble for most beginners in acoustics, but a measurement scale of this type appears necessary because of the tremendous range of amplitudes which common sound sources produce and which may subsequently be detected by the human ear.

Table 2.4 shows the relationship between the pressure levels and the db scale. A subjective interpretation of this scale is that the sound intensity approximately doubles for each 10 db; for example, 60 dB is considered by people to be twice as loud as 50 db. However, the interpretation of sound amplitude in relation to human response is

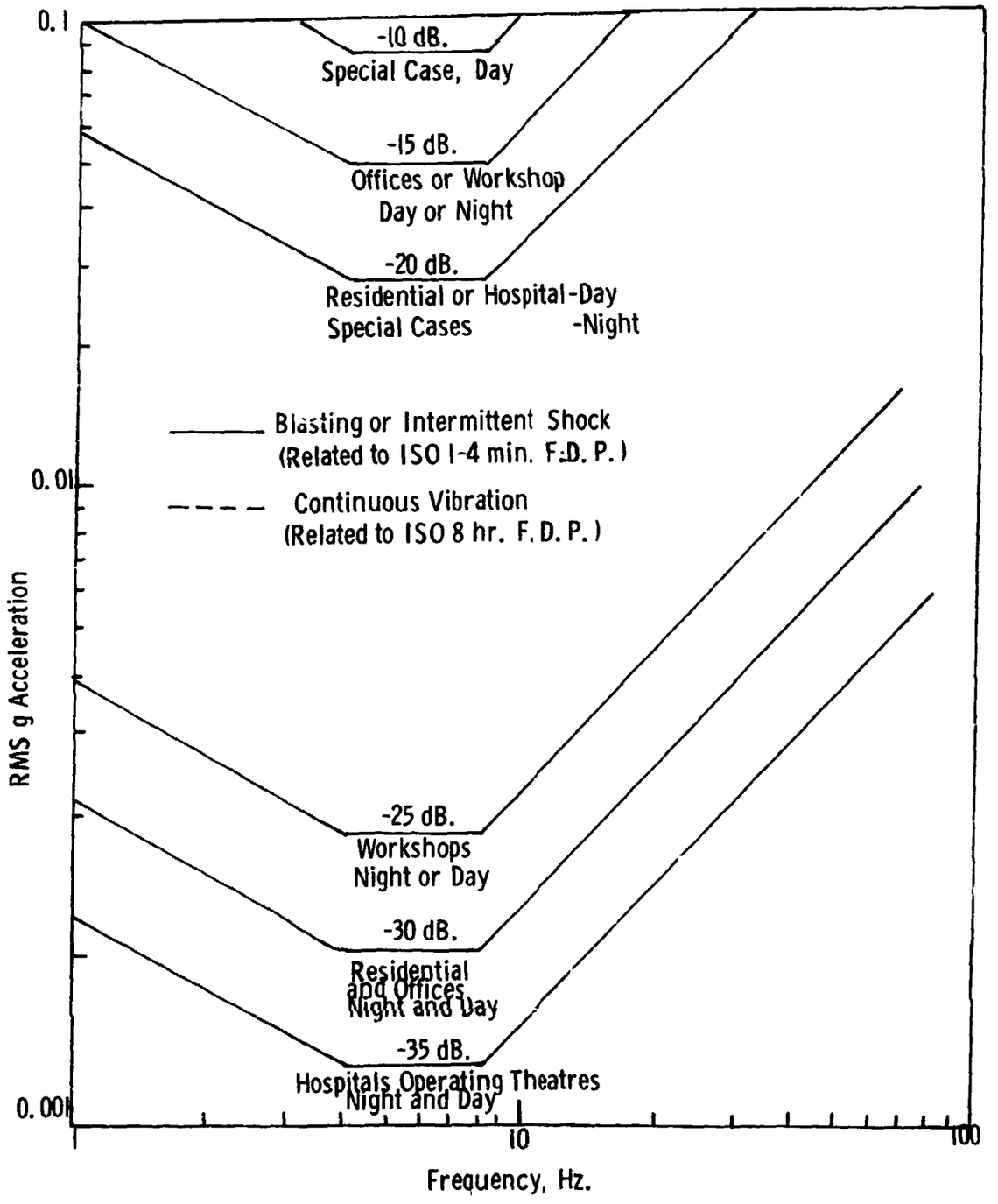


FIGURE 2.13
SUGGESTED LIMITS, BUILDING VIBRATIONS
Source: [42]

TABLE 2.4
DECIBEL SCALE RELATED TO PRESSURE LEVEL

Decibel Level	RMS Pressure Level
-20 dB	1/10 x Pref
0 dB	Pref
20 dB	10 x Pref
40 dB	100 x Pref
60 dB	1000 x Pref
80 dB	10,000 x Pref
100 dB	100,000 x Pref
120 dB	1,000,000 x Pref
140 dB	10,000,000 x Pref
Pref-.0002 microbars-2x10-10 dynes per square centimeter	

TABLE 2.5
CRITICAL NOISE EXPOSURE LEVELS

Sound Level	Effects
78-80 dB(A)	Safe
85 dB(A)	Hearing losses begin
90 dB(A)	Serious losses begin
95 dB(A)	50 percent probability of a hearing loss
105 dB(A)	Losses in all exposed individuals

These cutoffs refer to damage risks for prolonged exposures

Source: [53]

more complex than that simple rule-of-thumb may suggest. The human ear does not respond to all frequencies with equal efficiency. In fact its range of sensitivity is roughly from 20 Hz to 20,000 Hz with large variations from individual to individual. Within this range, greatest sensitivity is in the 500 Hz to 4000 Hz band. A number of measurement scales have been developed which account in various ways for the variation with frequency of the sensitivity of the human ear. [53, 54].

Physiological effects of noise are primarily associated with the human auditory system, which is the specific receptor of acoustic signals. Over a wide range of sound levels, the auditory system merely detects the signal and passes it along to the brain where it is interpreted. As mentioned earlier, the ear is not equally sensitive to all frequencies. Figure 2.14 presents the hearing threshold as a function of frequency and an equal loudness contour. A measurement scale based on this frequency weighting known as dB(A) is assumed to be a measure of the loudness of a sound. For noises with intensities below 80 dB(A), there are apparently no noise induced damages to the auditory system. Some hearing loss occurs for noises greater than 85 dB(A) and hearing loss occurs in all cases for individuals exposed continuously to noises of 105 dB(A) or greater [53]. Critical noise exposure levels are given in Table 2.5. Somewhat lower threshold levels for damage are given by Kryter [55].

Hearing loss is not the only danger from exposure to noise. Noise can cause the body to activate many vital neural and chemical processes in its defense. The resulting stresses, often emotionally precipitated, may result in severe physiological and mental impairment (e.g. ulcers, hypertension, insomnia, personality disturbances) if the body cannot cope with them. This may happen if prolonged exposure to noise causes a depletion of bodily defenses, or if noise-induced stress is added to other forms of stress. Since transportation noise is irregular and discontinuous, its most probable role will be as an additive stress on man, who may be already beset by various physical, social, and psychological stresses.

One of the major psychological responses to noise is annoyance. Other factors may be deterioration of motor performance and work efficiency, but the research on these matters is insufficient for detecting significant effects. A measure of the annoyance of a noise is given by the PNdB scale. It is based on tests similar to those which established the constant loudness contours leading to the dB(A) scale of measurement for loudness. Figure 2.15 shows an example of an equal noisiness contour as a function of frequency. The PNdB measure of noisiness weights the

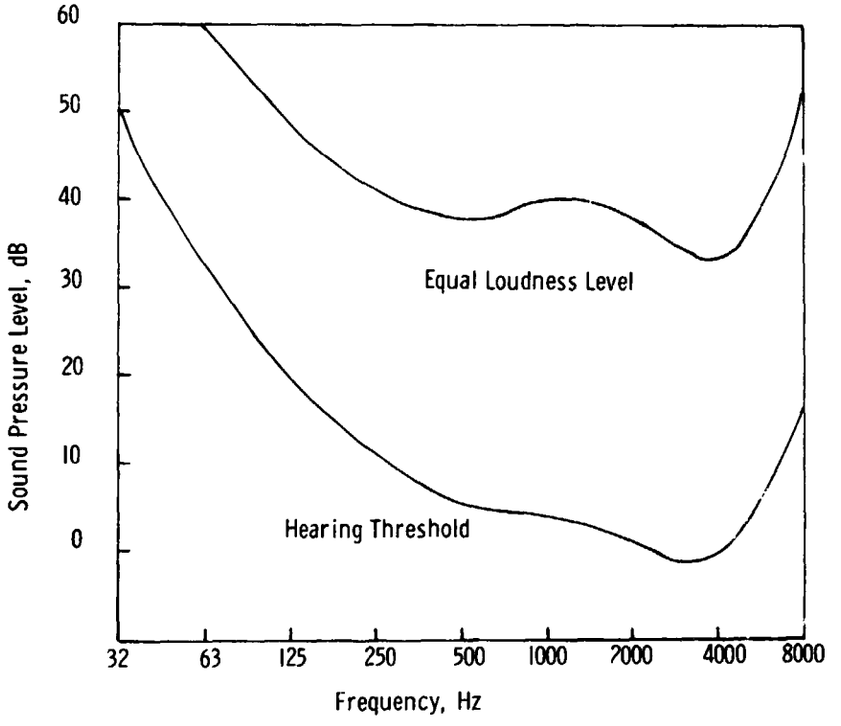


FIGURE 2.14
HEARING THRESHOLD AND EQUAL LOUDNESS CONTOURS
Source: [53]

frequency content of a particular noise according to this curve.

The principal human responses to noise are summarized in Figure 2.16.

2.3.2.2 Noise Interference With Speech

The effect of noise on the ability to communicate through speech is at once relatively easy to measure and of great importance in transportation design. Speech intelligibility is often measured by an articulation index (AI), which is related to other measures of intelligibility as in Figure 2.17.

It can be seen that an articulation index of at least 0.5 is required for barely reliable communication. The characteristics of the average speech signals must be known as well as the properties of the ear if speech communication is to be analyzed. Figure 2.18 shows the properties of idealized speech spectra; the information content is in the frequency range below 5000 Hz.

Beranek [56] has proposed that an effective and simple measure of effectiveness of person-to-person speech communication in the presence of noise might be obtained by considering the average sound pressure levels in the three octave bands 600-1200, 1200-2400, and 2400-4800 Hz. This average is called the SIL (Speech Interference Level). Table 2.6 shows the relationship between SIL, voice level, and separation for an articulation index of 0.5. A SIL less than about 55dB is seen to be required for ordinary level communication at a distance of three feet.

2.3.2.3 Masking Effect of Noise

Auditory presentation of information is recommended for the following common situations:

1. The signal is acoustic in its original form.
2. The signal provides a warning.
3 The visual information processing system is overloaded.

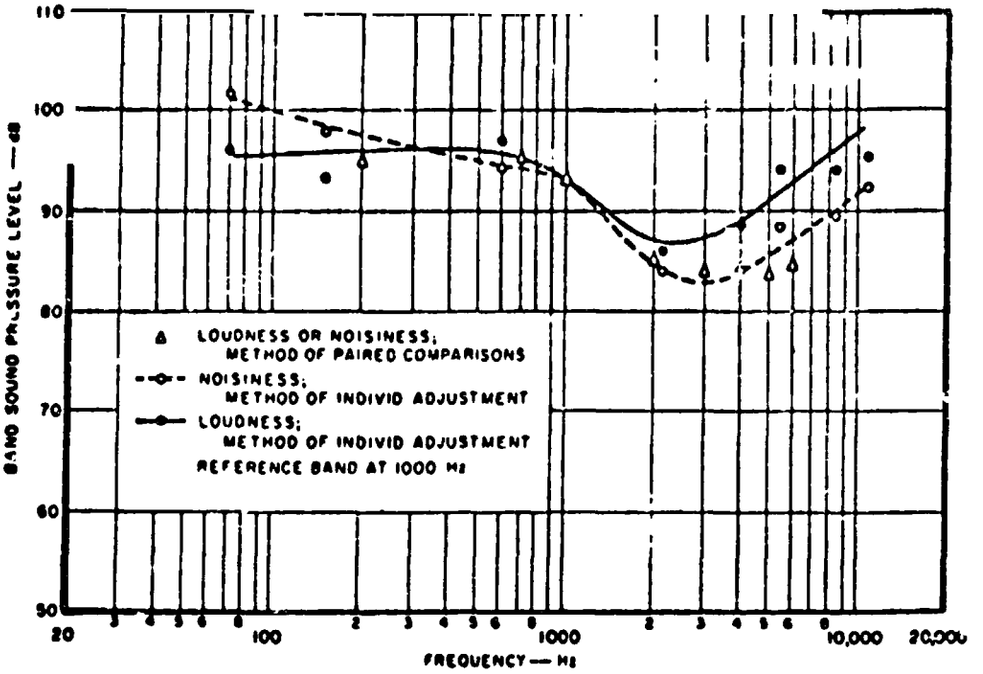
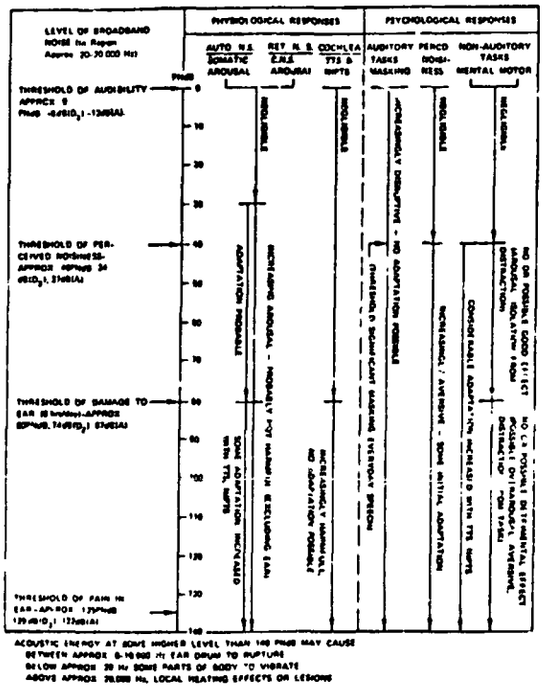


FIGURE 2.15
EQUAL LOUDNESS AND EQUAL NOISINESS JUDGMENTS
Source: [55]



Basic physiological and psychological responses of man to habitual environmental noise. Auto. N.S., Ret. N.S., and C.N.S. stand for autonomic, reticular, and central nervous systems, respectively.

FIGURE 2.16
BASIC PHYSIOLOGICAL AND PSYCHOLOGICAL RESPONSES OF MAN TO HABITUAL ENVIRONMENTAL NOISE
Source: [55]. Figure 287]

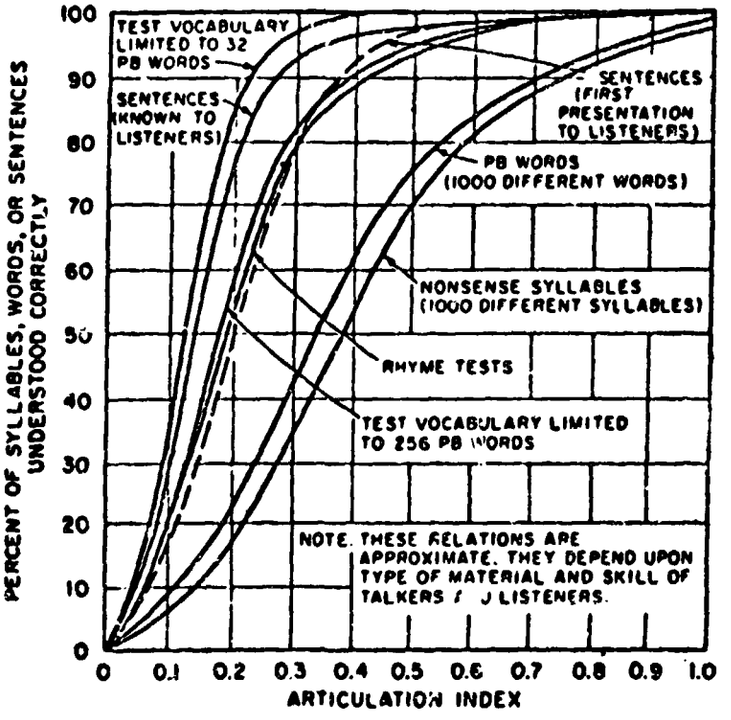


FIGURE 2.17
RELATION BETWEEN ARTICULATION INDEX AND VARIOUS MEASURES OF SPEECH INTELLIGIBILITY
Source: [55]

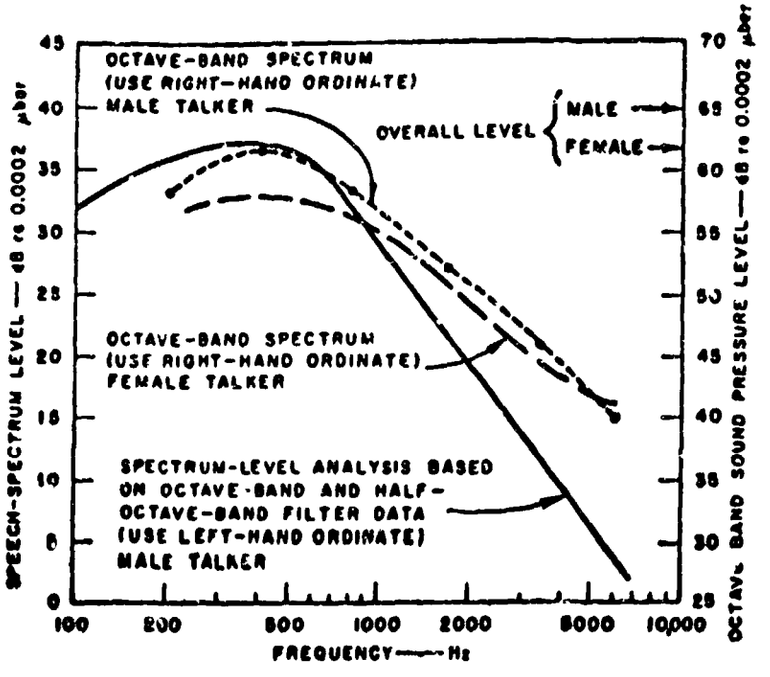


FIGURE 2.18
IDEALIZED SPEECH SPECTRA FOR MALE AND FEMALE TALKERS ONE METER FROM TALKER. NORMAL LEVEL EFFORT FOR TYPICAL, EVERYDAY TALKING CONDITIONS.
Source: [55]

TABLE 2.6
SPEECH INTERFERENCE LEVELS THAT PERMIT BARELY RELIABLE CONVERSATION, OR THE CORRECT HEARING OF APPROXIMATELY 75% OF PB WORDS, AT VARIOUS DISTANCES AND VOICE LEVELS

Distance between talker and listener (ft.)	Voice Level			
	Normal	Raised	Very Loud	Shouting
	Speech Interference Level (dB)			
0.5	71	77	83	89
1	65	71	77	83
2	59	65	71	77
3	55	61	67	73
4	53	59	65	71
5	51	57	63	69
6	49	55	61	67
12	43	49	55	61

Source: [56]

4. The receiver's head is not oriented so that he will notice a visual signal.
5. Vision is limited or impossible.
6. Signals must be differentiated from a background of non-signal noise.

The operator or passenger of any vehicle is frequently in an environment described by one or more of the above conditions. In considering the design of any transportation vehicle, the engineer must cope with two general sources of acoustic signals; those originating within the vehicle cabin, and those originating outside. The former include such items as passenger conversation, radio messages (radio sounds are classified as noise when they interfere with other signals), and warn signal indicators. The latter include warning devices such as horns, bells, sirens and, in some cases, the sounds made by vehicles (including the vehicle being operated by the receiver). Signals from both sources are masked by noise from both sources.

Reception of external acoustic signals by the vehicle operator is further complicated by the insulation built into the vehicle for protection against external noise generated by traffic and by the vehicle itself. Noise levels in high speed traffic on densely travelled highways are often as high as 85 to 100 PNdB. Insulation commonly used on many automobiles and busses will reduce the outside noise level by 15 to 25 decibels, preventing hearing interference, reducing annoyance and headaches, and providing a measure of comfort or luxury.

The masking problem generated by acoustic insulation in vehicles is the result of a basic psychophysical property of the auditory system; specifically, greater differences in intensity (dBA or PNdB) between signal and noise are required for signal detection when both are at lower levels than when both are at higher levels. (When the radio listener cannot hear a message over static he turns the volume **up** in order to increase his acoustic perception.) Thus, acoustic insulation in vehicles significantly decreases the detectability of external auditory signals. Moreover, the level of acoustic signal in-

tensity reaching the receiver vehicle is inversely proportional to the square of the distance from the source.

Recent research studies have confirmed the experiences of many motorists with respect to the extraordinarily short distances at which sirens on emergency vehicles can be just heard. The problem is especially acute when internal masking effects from a radio or tape player are also present. Under such circumstances, the **first** perception of the siren may occur at a distance of no more than 50 or 60 feet, hardly sufficient to allow for an evasive maneuver. When windows are open, external and airstream noise will cause significant masking. Recommended levels for acoustic warning devices are given in McCormick [1].

The following guideline is suggested:

Reliance upon auditory warning devices for detection beyond 200 feet under conditions of dense, high speed traffic or in areas having high ambient noise levels should be minimized. Flashing lights on emergency vehicles currently provide the best warning under such conditions.

2.3.2.4 Illumination

The requirements for a satisfactory lighting installation are (1) sufficient light of unvarying intensity on all principal surfaces whether horizontal, vertical, or oblique planes; (2) a comparable intensity of light on adjacent areas and on the walls; (3) light of a color and spectral character suited to the purpose for which it is employed; (4) freedom from glare and from glaring reflections; (5) light so directed and diffused as to prevent objectionable shadows or contrasts of intensity; (6) a lighting effect appropriate for the location and lighting units which are in harmony with their surroundings, whether lighted or unlighted; (7) a system which is simple, reliable, easy of maintenance, and in initial and operating cost not out of proportion to the results attained. The neglect of any one of these requirements may result in an unsatisfactory installation.

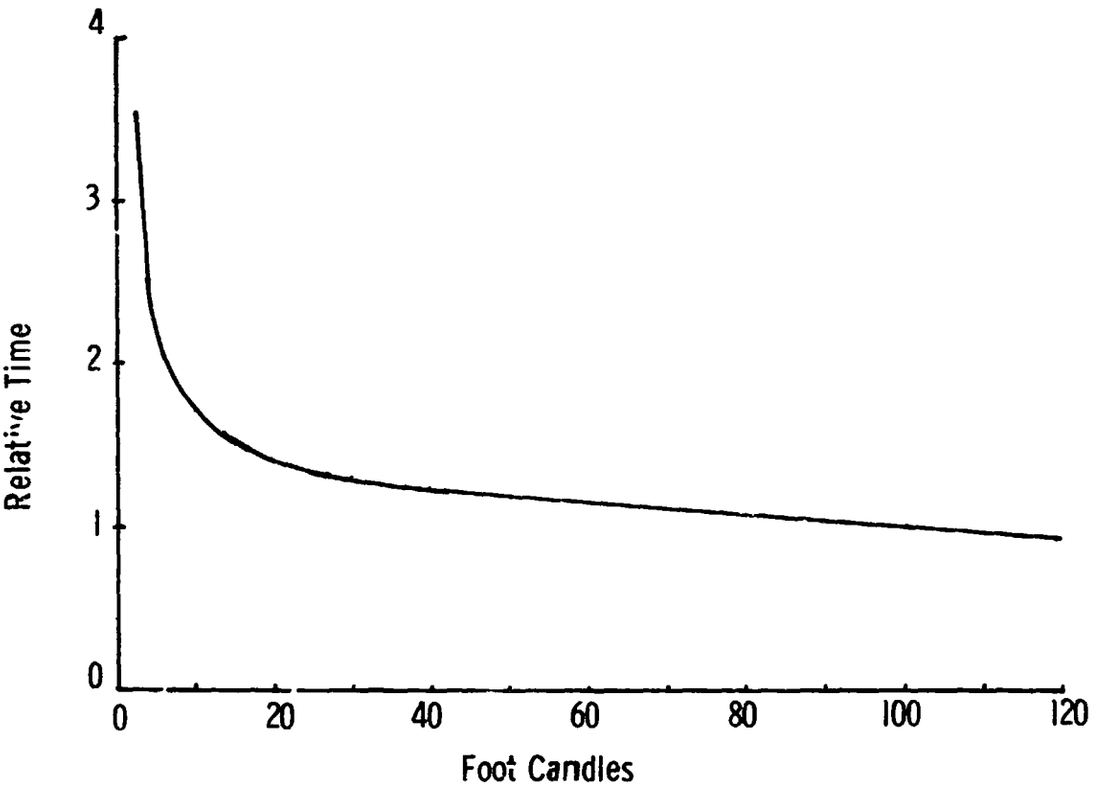


FIGURE 2.19
PERCEPTION TIME AS A FUNCTION OF ILLUMINATION (GENERAL ELECTRIC CO.)

Although the eye is capable of adjusting itself to perceive objects over a wide range of intensities, the speed of this perception and the ability to distinguish fineness of detail is improved as the intensity increases, until the intensity becomes so great that a blinding effect is produced. An intensity of illumination that will be so high as to produce a blinding effect is however far above the range of intensities utilized in artificial illumination. The effect of the intensity of illumination upon the length of time required for the perception of objects is shown in Figure 2.19. The effect of the intensity of illumination upon the length of time required for the discrimination of detail is shown in Figure 2.20. Categories of difficulty of seeing tasks with guide brightness and with footcandles for specified reflectance conditions are given in Table 2.7.

Glare is produced by brightness within the field of vision that is greater than the luminance to which the eyes are adapted to cause discomfort annoyance or actual loss in visual performance and visibility. Direct glare is caused by light sources in view, and specular glare is caused by reflections from surrounding polished or glossy surfaces.

Visual discomfort from glare is a common experience and much attention has been given to this problem by lighting manufacturers, particularly General Electric Co. [99] in their development of **discomfort glare rating** (DGR). The DGR of a system takes into account most of the situational factors that influence visual comfort: (1) room size and shape; (2) room surface reflectances; (3) light distribution; (4) illumination level; (5) number and location of lights; (6) luminance of entire field of view; (7) observer location and line of sight; and (8) equipment and furniture. The Illuminating Engineers Society Subcommittee on Glare [100] set conditions on glare derived from the DGR criterion.

The distribution of light also has an influence on visual performance. The luminance ratio (the ratio of the luminance of a given area and a surrounding area) seems to be an important variable in the enhancement of visual performance. Table 2.8 shows the IES recommended luminance ratios

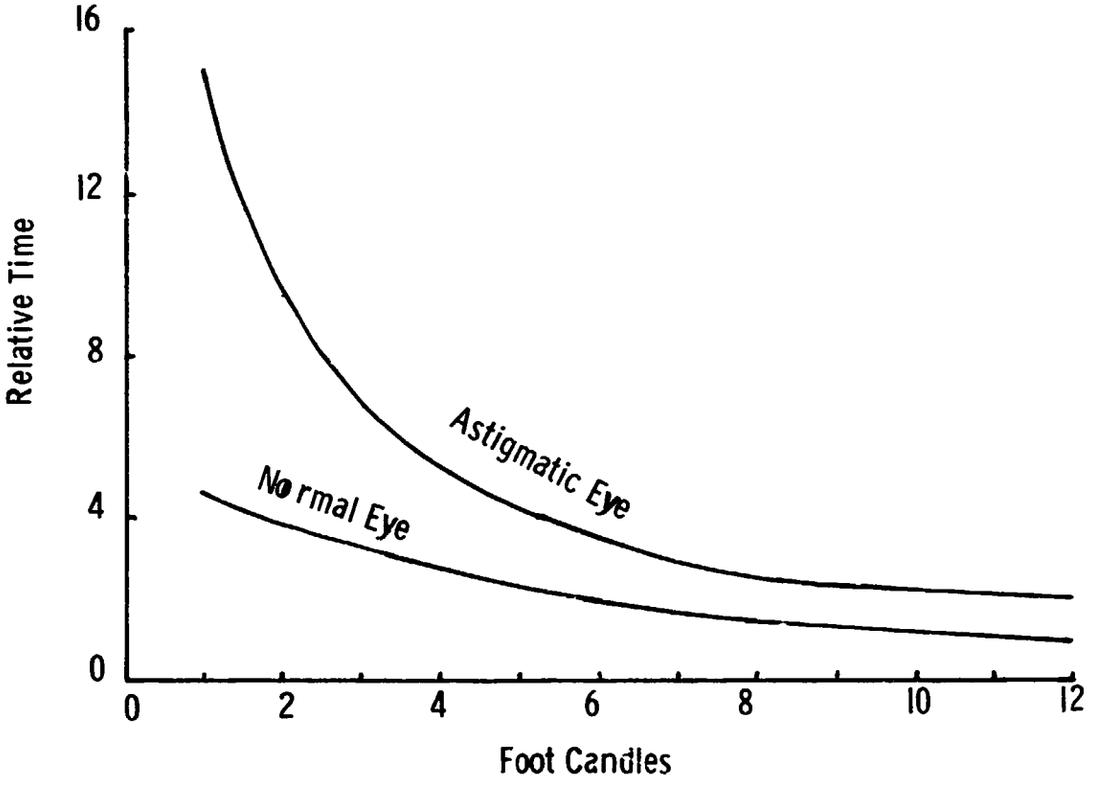


FIGURE 2.20
DISCRIMINATION TIME AS A FUNCTION OF ILLUMINATION (GENERAL ELECTRIC CO.)

TABLE 2.7
CATEGORIES OF DIFFICULTY OF SEEING TASKS WITH GUIDE BRIGHTNESS AND WITH FOOTCANDLES FOR SPECIFIED REFLECTANCE CONDITIONS

Category of seeing task	Guide brightness fL	Footcandles for specified reflectance conditions 90%	50%	10%
A. Easy	Below 18	Below 20	Below 36	Below 180
B. Ordinary	18-42	20-45	36-84	180-420
C. Difficult	42-120	45-133	84-240	420-1200
D. Very Difficult	120-420	133-455	240-840	1200-4200
E. Most Difficult	420 up	455	840	4200

Source: Adapted from *Illuminating Engineering*, [98]

as a function of environmental situations, which may be used as a guide for illumination of transportation facilities. Recommended minimum levels of illumination for many types of vehicles and facilities are given in Reference 2.98.

Good street and highway lighting (often called traffic safety lighting) not only promotes safer conditions for drivers but provides greater safety for pedestrians as well. It enhances the community value of a street by its attractive appearance, which is usually reflected in higher property values.

In order to achieve truly effective street lighting, it is essential that the installation be well planned. Planned street lighting should follow the American Standard Practice for Roadway Lighting of the Illuminating Engineering Society and will involve the following considerations.

1. Traffic classification of the street
2. Determination of the proper lighting intensity for the street classification
3. Selection of luminaires according to the light distribution needed for the street
4. Determination of the mounting height of the luminaire above the road surface and the proper linear spacing between luminaires.

Table 2.9 shows the vehicular traffic volume classification recommended by the Street Lighting Committee of the Institute of Traffic Engineers. It is further recommended that all streets be further classified by the volume of pedestrian traffic during the night hours of maximum usage:

Light or no pedestrian traffic, as on streets in residential or in most warehouse areas, on express, elevated or depressed roadways or on open highways.

Medium pedestrian traffic, as on secondary business streets and on some industrial streets.

Heavy pedestrian traffic, as on business streets.

TABLE 2.9
VEHICULAR TRAFFIC VOLUME CLASSIFICATION

Classification of Traffic	Vehicles per Hour
Very light traffic	Under 150
Light traffic	150-500
Medium traffic	500-1200
Heavy traffic	1200-2400
Very heavy traffic	2400-4000
Heaviest traffic	Over 4,000

*Maximum night hour in both directions.

Source: IES, [98]

TABLE 2.8
RECOMMENDED LUMINANCE RATIOS FOR OFFICES AND INDUSTRIAL SITUATIONS

Areas	Recommended Maximum Luminance Ratio	
	Office	Industrial
Task and adjacent surroundings	3:1	
Task and adjacent darker surroundings		3:1
Task and adjacent lighter surroundings		1:3
Task and more remote darker surfaces	10:1	10:1
Task and more remote lighter surfaces	1:10	1:10
Luminaries (or windows, etc.) and surfaces adjacent to them	20:1	20:1
Anywhere within normal field view	40:1	40:1

Source: From IES lighting handbook, [98 fig. 11-11, p. 11-7, and fig. 14-2, p. 14-3.]

TABLE 2.10
RECOMMENDATION FOR AVERAGE HORIZONTAL FOOTCANDLES IN LUMENS PER SQUARE FOOT

Roadways (Other than expressways or freeways)				Expressways and freeways	
Roadway Classification	Area classification			Classification	Expressways
	Downtown	Inter-mediate	Outlying and rural		
Major	2.0	1.2	0.9	Continuous urban	1.4
Collector	1.2	0.9	0.6	Continuous rural	1.0
Local or minor	0.9	0.6	0.2	Interchange urban	2.0
				Interchange rural	1.4

Source: IES, [98]

The proper lighting intensity for each roadway classification may be determined from Table 2.10. These recommended foot-candle levels are the average values on the roadway between curbs. The lowest intensity at any point should not be less than one-fourth of these values. The figures given are based on favorable pavement reflectance of the order of 10 per cent. When the reflectance is low (3 per cent or less), the illumination recommended should be increased 50 per cent. When the reflectance is unusually high (20 per cent or more), the recommended values may be decreased 25 per cent.

2.3.2.5 Barometric Pressure

The discomfort caused to a person by a reduction in pressure in his environment, depends on the rate of the reduction and whether his middle ear pressure can adjust to it. A pressure differential of 0.06 to 0.10 psi across the tympanic membrane is slightly uncomfortable; 0.19 to 0.29 psi results in a lessened sound perception; and 0.29 to 0.58 psi causes considerable discomfort and possibly pain and vertigo [101]. Differential pressures above 1.0 psi may rupture the membrane. In aircraft emergency climbs, the cabin pressure change may be about 1.0 psi over a period of 60 seconds, or at 0.017 psi per second. If a tunnel is entered at high speed, a relatively short time is available for the air to adjust. The car pressure change in the New Tokaido Line, for example, is about 0.05 psi in about 4.5 seconds, or 0.01 psi per second [102]. But in so short a time, the passenger's ears would probably not adjust themselves, so that momentary discomfort may be experienced. For pressure changes outside the car of as much as 0.20 psi, it seems necessary that high speed trains be air tight and have valves that close automatically on ventilation equipment [103]. In 1966, tests of pressure variations in high speed train cars when two 12-car trains pass each other in a tunnel were conducted; with a hole about 6 inches by 15 inches open in the floor, a 1.0 psi pressure change was measured [104].

2.3.2.5 Nystagmus and Intermittent Photic Stimuli

Optokinetic (train) nystagmus occurs when a series of objects move across a person's visual field and the eyes follow one object across the field, move rapidly back to the next object, follow it across, move back to the next and so on. Dizziness and nausea are normally produced when the stimulus rate is from 2 to 12 objects passing per second. Figure 2.21 defines the critical region for nystagmus on the basis of present evidence.

When a light is rapidly flashed at a rate above about 20 flashes per second it appears to be continuous, except when the eye is

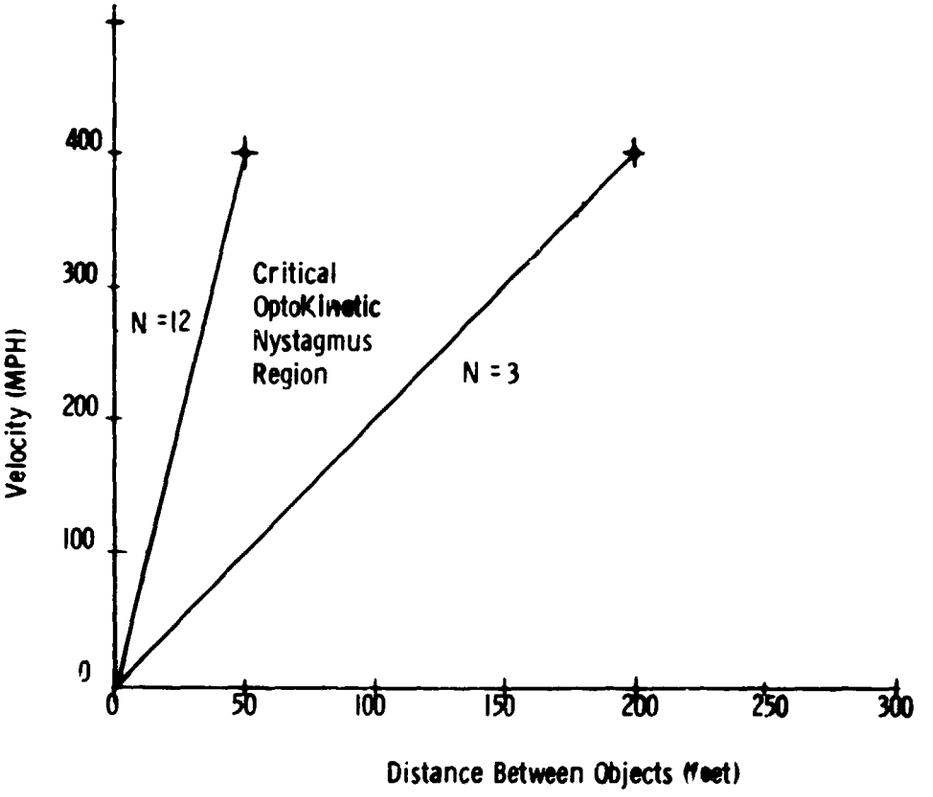


FIGURE 2.21
CRITICAL OPTOKINETIC NYSTAGMUS REGION

Source: [105]

moving. When the light flashes slowly, at one or two times a second, it appears to be turning on and off. Between these rates a sensation called flicker is produced. Intense flicker at frequencies of between five and twenty cycles per second make certain people see color, patterns, or movement [105]. They may become confused and feel anxious or disoriented. Attacks resembling epilepsy may be produced in susceptible people. Flicker evokes responses in the cortex of the brain at the back of the head which is concerned with vision, and the evoked responses have the same frequency as the flicker. At one or two frequencies the amplitude of the one evoked response may be up to five times as large as at other frequencies. Sunlight passing between rotating helicopter blades has caused this difficulty [105]; the effect appears to be related to the brightness of the light, its wave length, and the dark-light ratio of the flashing. Flicker effect may come into play in high speed rail transit in the design of pole spacing and window arrangements [13]. The most prominent range of frequencies at which flicker symptoms occur is between 9 and 15 cycles per second. It has been suggested that the frequencies of flicker which disturb people may be related to the frequency of the alpha ruthm of the brain which is about 10 cps. However, it is not clear what the causal relationship is, if there is one.

2.3.2.6 Temperature and Humidity

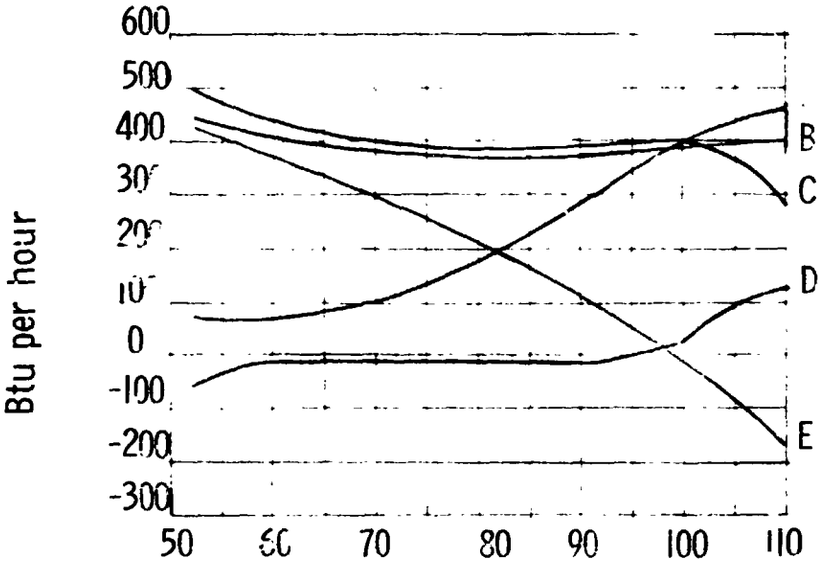
Passenger comfort in a vehicle or station is strongly influenced by the degree of control of temperature and humidity provided. Temperature comfort is principally affected by the heat produced and stored by the body, and by heat exchange with surroundings through evaporation, convection, and radiation. The rate of body heat production is always positive. The rate of change of the body stored heat may be positive or negative, depending upon whether heat is being stored or depleted, resulting in an increase or decrease in body temperature. Under normal circumstances (when the dew point of the air is below the body surface temperature), the rate of evaporation heat loss is positive, that is, heat production compensates for this loss. Body heat production is mainly dependent on muscular activity and may vary from 400 BTU/hr for a resting seated adult to more than 2500 BTU/hr for heavy work. Typical values are given in Table 2.11.

Convection heat exchange may be in-

TABLE 2.11
ESTIMATES OF BODY HEAT PRODUCTION
(154-lb. Man With No Rest Pauses)

Kind of Work	Activity	M Btu/hr
	Sleeping	250
	Sitting quietly	400
Light Work	Sitting, moderate arm and trunk movements (e.g., desk work, typing)	450-550
	Sitting, moderate arm and leg movements (e.g., playing organ, driving car in traffic)	550-650
	Standing, light work at machine or bench, mostly arms	550-650
Moderate Work	Sitting, heavy arm and leg movements	650-800
	Standing, light work at machine or bench, some walking about	650-750
	Standing, moderate work at machine or bench, some walking about	750-1000
	Walking about, with moderate lifting or pushing	1000-1400
Heavy Work	Intermittent heavy lifting, pushing or pulling (e.g., pick and shovel work)	1500-2000
	Hardest sustained work	2000-2400

Source: [106]



Legend:

A. Heat Evaporation Rate e
B. Heat Production Rate m
C. Total Heat Loss Rate
D. Body Stored Heat Rate s
E. Radiation and Convection Heat Rate c and r

FIGURE 2.22
BODY HEAT PRODUCTION AND ENVIRONMENTAL HEAT EXCHANGES
Source: [108]

creased by lowering the air dry bulb temperature, or by increasing the convection heat transfer coefficient through an increase in air velocity. Therefore, in order to remove heat in a convective mode from the body in a hot environment, one can either increase the ventilating air velocity or decrease the dry bulb temperature of the surrounding air. Radiation heat exchange may be increased by lowering the surrounding surface temperatures. Typically, the surrounding surface temperature is approximately equal to the air dry bulb temperature, so that convective and radiative heat rates can be combined into what is usually referred to as the rate of sensible heat loss from the body. The evaporative heat loss from the body is dependent on the mass transfer coefficient and the air humidity ratio for a given body surface temperature. The mass transfer coefficient is sensitive to air velocity such that an increase in air velocity results in an increase in evaporation. A decrease in the air humidity ratio (more commonly referred to as the relative humidity) also results in a higher evaporative heat loss. The rate of change of body stored heat is directly proportionally to body temperature and is ordinarily not zero. It was first discovered by Dubois [107] that stored body heat may be small where body exercise and environmental conditions are stable and may be of sizable magnitude where environmental conditions are unstable and where abnormal exposure occurs. Figure 2.22 summarizes the heat exchanges for a healthy young male, clothed and seated at rest.

At lower air temperatures body heat loss is predominantly controlled by the convective and radiative modes; at higher temperatures the evaporative loss becomes the controlling mode. At elevated air temperatures, rates of transfer by convection and radiation become negative (the body is absorbing heat) and evaporation must offset these heat gains as well as body heat generation. The human body has involuntarily-initiated regulation means for adjusting itself to either hot or cold exposures. There is a narrow range of environmental condition at which man's body does not need to take any action in order to maintain his heat balance normally referred to as the neutral point for that individual. If through a decrease in air temperature or an increase in air flow velocity the heat balance is disturbed, the body thermal regulatory system enters into a zone of vaso-motor regulation against cold. In this zone contriction of blood vessels will normally maintain proper core temperature. Beyond this temperature range, the core temperature will decrease unless the body further adjusts, increasing heat production by a spontaneous increase in activity (by increasing muscular tension and by shivering) [109]. Such conditions are referred to as the zone of metabolic regulation against cold. Below this level, the body enters a zone of inevitable body cooling. On the hot side of the neutral zone, there is a zone of vaso-motor regulation against heat. An increase in blood flow through the skin occurs which increases the conductance of the superficial tissues and allows the body to maintain its heat balance. If this increase in blood flow will not maintain the heat balance the body enters the zone of evaporation regulation. In this zone, the provision of water, through the operation of the sweat glands, promotes evaporative cooling. Above this zone the body enters a zone of inevitable body heating (interior body termperature will rise) where the hazards are heat exhaustion is due to failure of normal blood circulation and heat stroke in which body core temperatures may rise to 105° F or higher. At these core termperatures sweating ceases and the subject may enter a coma with death imminent. A minor disability may be heat cramps resulting from loss of salt by excessive perspiration.

Human thermal comfort is affected not only by the physical and physiological factors just cited, but also by psychological factors. The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) has been studying human reactions to environmental temperature, humidity and air velocity since 1923. This research has resulted in an **effective temperature index**. The effective temperature incorporates relative humidity, dry bulb temperature, and air velocity such that trained subjects perceived the environmental condition as indicating the same feeling of warmth or cold as slowly moving saturated air at the effective temperature. Figure 2.23 shows a nomograph of effective temperature as a function of dry bulb temperature, wet bulb temperature, and air velocity. The practical application of **effective temperature** (ET) has resulted in the ASHRAE Comfort Chart in Figure 2.24. This chart is applicable to a reasonably still air (20 to 25 ft. per minute), to situations where occupants are doing light work or seated at rest and to spaces where surrounding surfaces are at the temperature as the dry bulb ambient temperature of air.

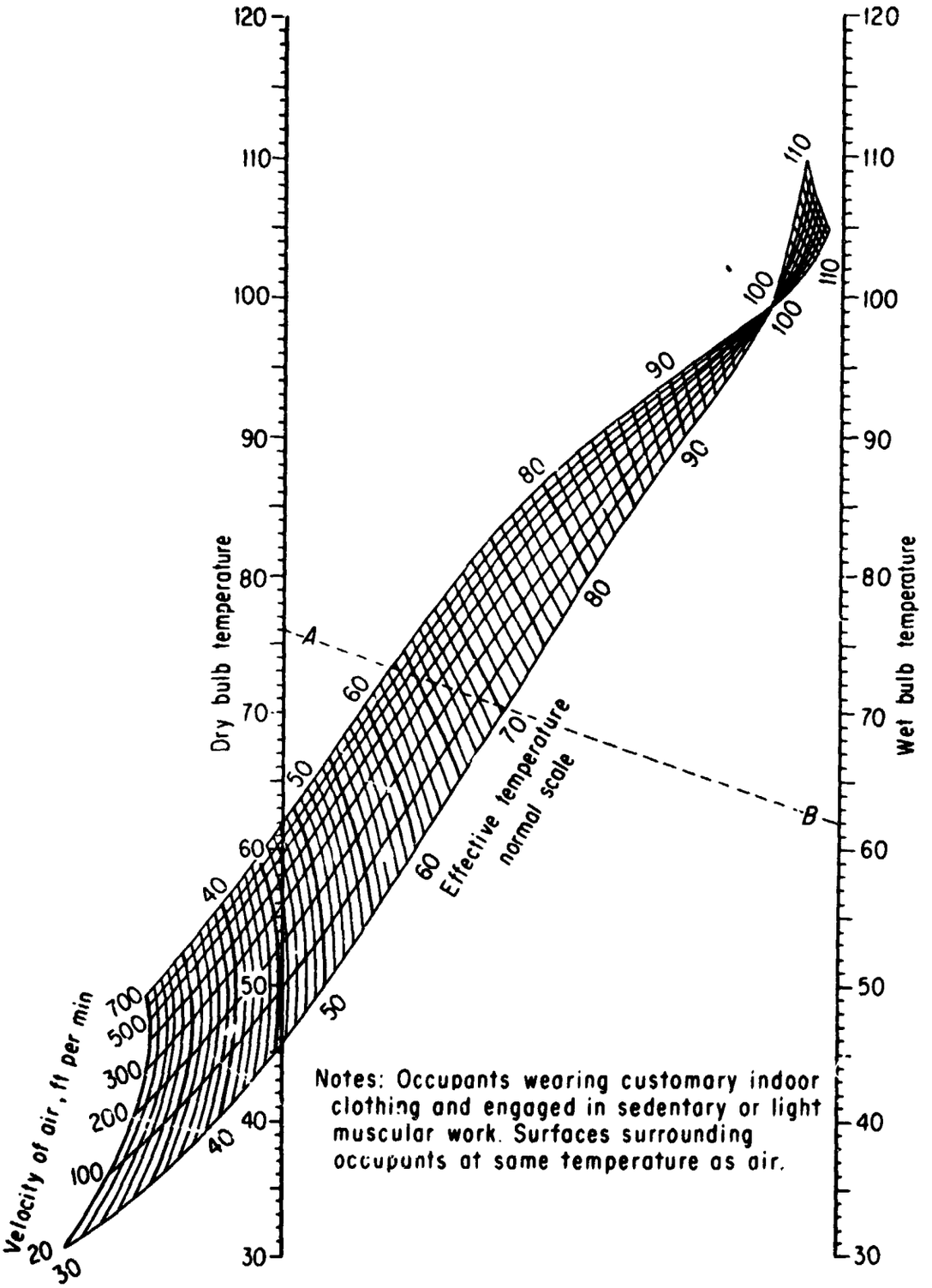


FIGURE 2.23
VARIATION OF EFFECTIVE TEMPERATURE WITH AIR VELOCITY

Source: [106]

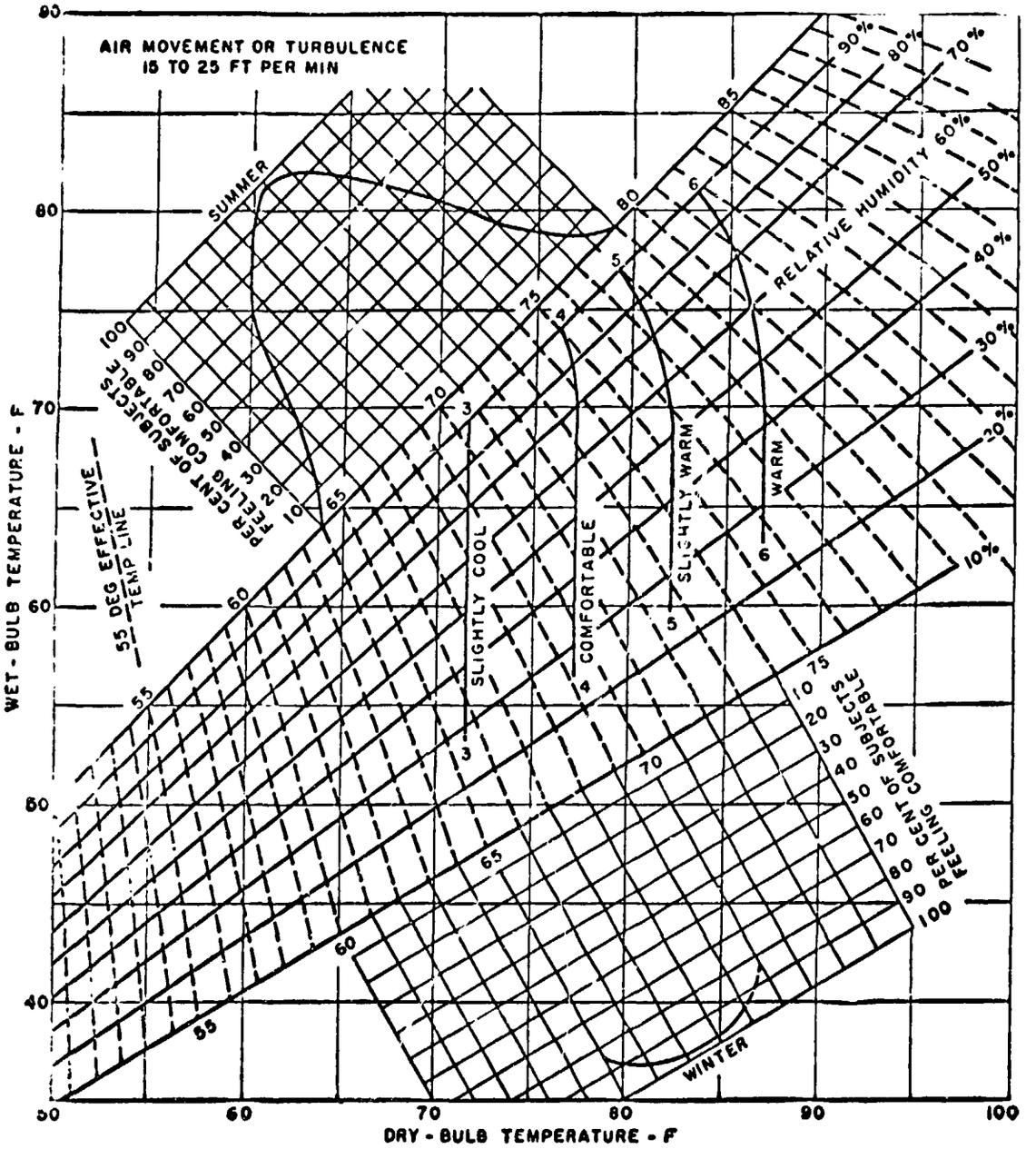


FIGURE 2.24
ASHRAE COMFORT CHART

Source: [106]

The distribution curves in the upper and lower portions of the graph indicate that the maximum percentage of people should be comfortable in summer about 71 ET and in winter about 68 ET. Although an effective temperature line defines the various combinations of conditions which will induce like sensations of warmth, it is not implied that like sensations of comfort will be experienced along the entire length of an effective temperature line. Some degree of discomfort is possible at very high or very low humidities, regardless of the effective termperature. The four curved lines of relative comfort labeled slightly cool comfortable, slightly warm, and warm were generated by subjective opinions during a three-hour exposure in an environmentally controlled room. The vertical lines seem to indicate that on these lines relative humidity has no effect on feelings of **comfort**, but it certainly has an effect of feelings of **equal warmth** (as represented by ET lines). The common criticism of the ET index is that it ignores radiative effects such as one might encounter in a vehicle with bright sunlight or radiative effects from surrounding walls at temperatures different from the air temperature. The wall effects can be included in the ET scale by including 0.5° F change in ET for every 1° F change in wall temperature to ambient temperature differential. Other investigators have taken radiative energy into account but have ignored humidity and air flow [110, 111] in their operative temperature. Although studies have shown ET to have an inherent error as an index of physiological effect, especially under severe environmental conditions, ET is the best known and most widely used composite scale of environmental conditions [112] .

2.3.2.7 Air Quality

In addition to temperature and humidity control, purity of air also has an important role in human comfort and health. Deterioration of air quality is due principally to chemical and particulate contamination, especially atmospheric intoxicants, and to odors. Air pollutants are due mostly to internal combustion engine emissions in the forms of oxides of carbon, sulfur, and nitrogen and hydrocarbons. Each of these pollutants is reviewed below.

Carbon dioxide (CO2) is introduced into the air by industrial and automotive processes and also as a by-product of body metabolism. The short-term physiological effect of CO2 is unconsciousness, which can occur in from one to ten minutes at concentrations of 8-10 percent CO2 in inspired air [114] . CO2 concentration can be controlled by proper ventilation. A maximum concentration of CO2 is 0.5% is allowed on a continuous prolonged exposure although it takes 1.5% to produce a physiological change and 3.0% to produce a performance decrement [115] .

Carbon monoxide (CO) is an odorless undetectable gas present in the atmosphere due to incomplete combustion. Its chief physiological effect is to reduce the availability of oxygen for metabolic processes by a reduction of arterial-oxygen saturation. CO combines with hemoglobin (Hb) in such a way that it not only prevents the Hb from carrying oxygen to tissue cells but also such that the Hb gives up the oxygen less readily. The consequences of CO poisoning are given in Table 2.12. Figure 2.25 shows levels of CO uptake by men. Figure 2.26 shows the effects

TABLE 2.12
SYMPTOMS OF CARBON MONOXIDE POISONING

COHb in blood (%)	Resulting symptoms
0-10	None subjectively noticeable, but initial visual impairment is revealed in objective tests.
10-20	Tightness across forehead, slight headache, flushed complexion.
20-30	Headache with throbbing in temples, breathlessness from any exertion.
30-40	Severe headache, weakness, dizziness, dimness of vision, nausea, and vomiting with possibility of collapse.
40-50	All preceding symptoms with increased pulse rate and respiration and greater possibility of collapse.
50-60	Loss of consciousness, with increased or irregular respiration, rapid pulse, and possibility of coma with convulsions.
60-80	Coma, convulsions, depressed heart action, respiratory failure and possibility of death.

Source: [115, Table 10-10]

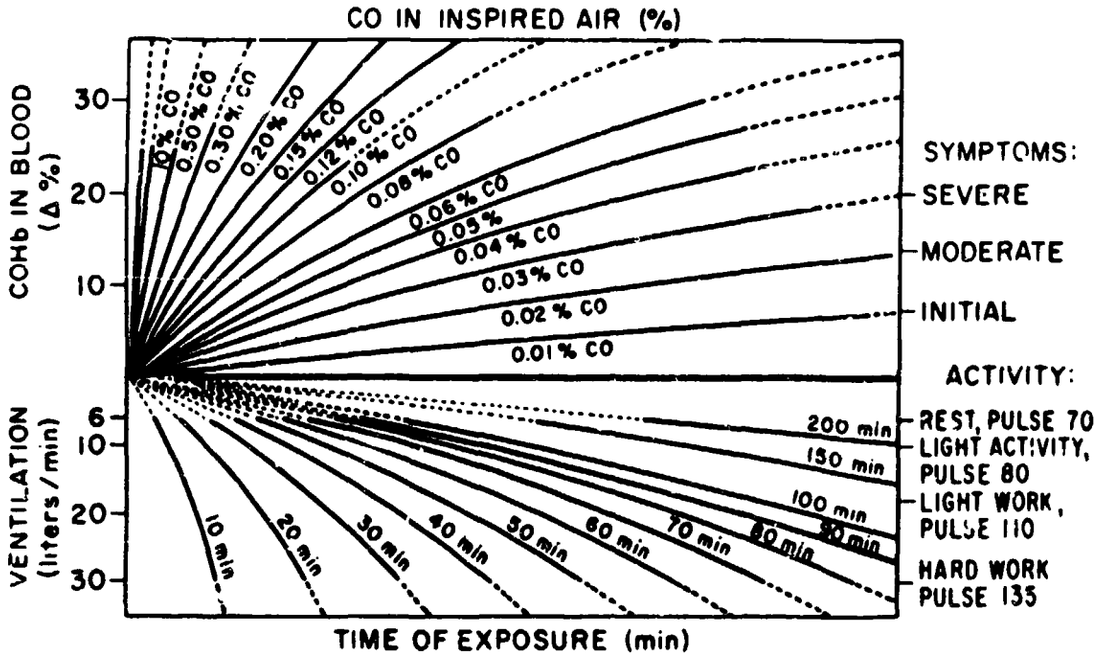


FIGURE 2.25
CARBON MONOXIDE UPTAKE FOR NORMAL MEN
Source: [116]

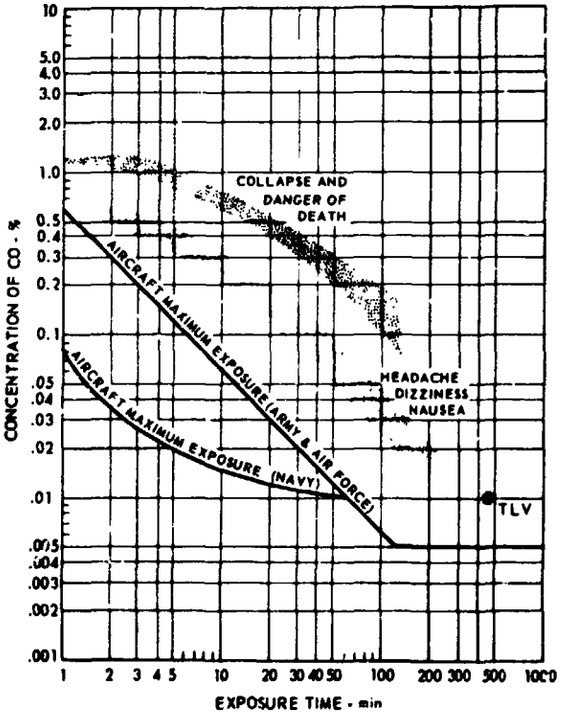
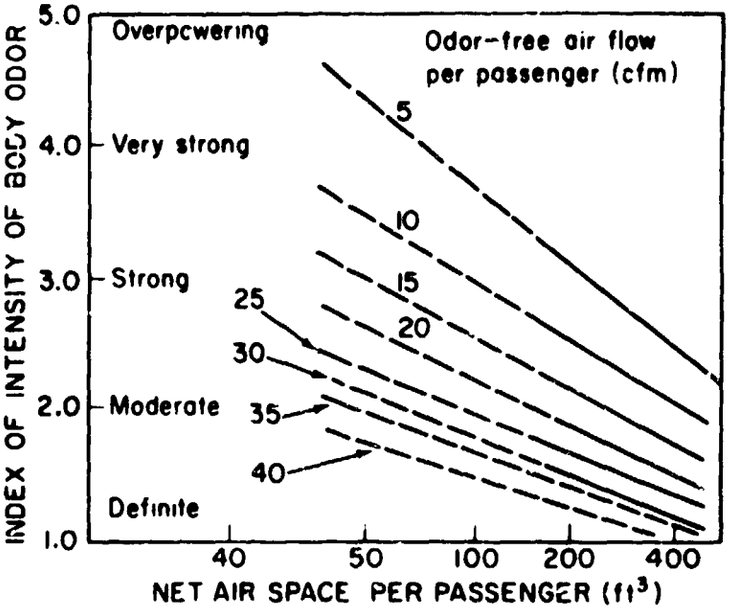


FIGURE 2.26
EFFECTS OF CO ON MAN AS A FUNCTION OF EXPOSURE TIME AND CONCENTRATION
Source: [2]



Ventilation requirements related to net air space and body odor. Solid parts of curves are based on experimental data; dashed portions are extrapolations of conditions found in aircraft.

FIGURE 2.27
NET AIR SPACE PER PASSENGER

Source: [114]

of carbon monoxide on man as functions of concentration and exposure time. Milder effects are shown as a lightly shaded band of exposure times and concentrations, while dangerous or lethal times and concentrations are grouped in the heavily shaded band. The solid lines are the exposure limits set by the military services for aircraft. The point marked at 0.01% CO (100 ppm) and 480 minutes is the current Threshold Limit Value (TLV) for 8-hours-a-day exposure in industry. For sea level work Morgan recommends 0.003% CO (30 ppm) or 4% COHb as a maximum for long term exposure while other investigators recommend 100 ppm [117, 118].

A somewhat less quantifiable air pollutant but one which causes totally unnecessary discomfort for non-smoking passengers is tobacco smoke. Vehicle air conditioning systems should have the necessary capacity to handle this. But when they don't, "no smoking" should be enforced.

Oxides of sulfur, primarily sulfur dioxide (SO_2), and oxides of nitrogen (N_2O, NO, NO_2, N_2O_4 and N_2O_5) are not very important for internal environment, but have a strong effect on general environmental air quality. They are left, therefore, for later treatment. Hydrocarbon pollution and ozone (03), for the same reasons, also are deferred.

Ventilation is an effective means of removing the contaminated air in an enclosed space by dilution. In this process the air vitiated with objectionable body odors, gaseous odors, irritants, particulates that obscure vision, and toxic matter is replaced by outside air. Recommended values for fresh air supply in order to meet maximum allowable pollutant concentrations can be found in many heat and ventilation engineering handbooks. Figure 2.27 shows the ventilation required to eliminate body odors as a function of air space allotted per person. The index used is based on the intensity of small sensations which are assumed to vary logarithmically with the concentration. Table 2.13 although based on controlled laboratory conditions, suggests minimum requirements for odor-free air that might be used in transportation design.

2.3.3 The Social and Psychological Environment

The passenger riding a mass transit vehicle or waiting in a terminal building is

subjected to social stimuli as well as to physical stimuli that evoke psychological responses. He may feel crowded; he may converse with others or join them at a bar; he even may fear the strangers who are his fellow travellers. Much stimulation comes from other people. His physiological responses to physical stimuli like noise and vibration are relatively easy to measure and quantify, as previous discussion has shown, but how does he react to colors, to light and shade, to the appearance of his surroundings? These factors are not so easily measured nor even well understood. Even his very involvement with the travel process, with the transport mode he has chosen, may have an effect on his image of himself. Such socio-psychological considerations raise important questions that elude well-defined answers, but they must be examined, for they are at the roots of his attitudes and behavior and they influence his views of transportation.

2.3.3.1 Personal Space, Crowding, and Social Interaction

People often travel with others, sometimes by choice, frequently because there is no other alternative. The conditions under which the traveller confronts his fellow travellers, the risk of disagreeable social interaction, and the extent to which he is able to retain some privacy and personal territory, radically influence his travel choices. Personal space has been described as a bubble or invisible envelope which a person marks out around himself to regulate his territory and the spacing between himself and others. [76] Outside the envelope is an emotionally charged zone of social stimulation against which the individual attempts to protect himself. Its limits, and the processes by which he fixes them, are not well known, but there is ample evidence that invasion, or threat of invasion, of personal space by crowding, for example, can produce emotional stress and physical distress, as well as behavior alterations.

Many behavorial studies of the ways in which animals share space suggest that an individual either refrains from going where he is likely to be involved in disputes over territory or, based on his knowledge of who is above and below him, engages in ritualized domination-subordination behavior rather than actual combat [76] If territorial rights are well specified, associated dominance behavior likewise will be specified. Humans appear to play by the same rules.

It may be possible to trade off territoriality and disagreeable social interaction. That is, if each passenger has his own assigned area and a certain amount of control over the social interaction that takes place, he may be able to avoid the types of social interaction

TABLE 2.13
MINIMUM ODOR-FREE AIR SUPPLY

Requirements to Remove Objectionable Odors Under Laboratory Conditions		
Type Occupants	Air Space per Person (ft^3)	Odor Free Air Supply per Person (CFM)
Seated Adults of Average Socio-economic Status	100	25
	200	16
	300	12
	500	7
Laborers	200	23
Grade School Children of Average Socio-economic Status	100	29
	200	21
	300	17
	500	11
Grade School Children of Lower Socio-economic Status	200	38
Children Attending Private Grade School	100	22

which he considers disagreeable. The former practice in Southern States of separate seating for blacks and whites in buses was an extreme case of limiting the kinds of social interaction which might occur. When boarding a bus, train, or plane, the passenger is very concerned with the types of social interaction which may occur according to his choice of seats. He has such options as sitting with someone whose appearance suggests compatibility or leaving an empty seat on the chance that whoever takes it will be compatible. The risk of experiencing disagreeable social interaction is important to the traveller and affects his mode choice. Control over personal space and over choice of companions has much to do with the attractiveness of the private automobile and its preference over public mass transit. Substantial control is retained even when the traveller joins a car pool arrangement.

Spatial invasion is the unwanted intrusion by an individual into another's personal space. The boundary a person wishes to keep depends importantly on what sort of social interaction he desires, what sort of fellow passengers are present, and the nature of the trip. Often passengers will avoid social interaction on a subway, train or bus by withdrawing in various ways. They may stare straight ahead or read the newspaper or use other methods to avoid contact. This behavior contrasts sharply with a group beginning a holiday travel tour. In general, face-to-face seating is the most threatening posture to those who fear spatial invasion, because their comfort boundary against the approach of strangers extends a greater distance frontwards than to the sides or to the rear. An exception to this rule is when a person fears that others might do him physical harm, in which case he seeks to protect his rear and to take the safest position along a wall where everyone can be seen. When safety is not at stake and the passenger simply wants to avoid unpleasant social interaction, the face-to-face position is threatening because it offers the **possibility** of visual, auditory, and olfactory invasions. Visual invasions occur, for example, when a person feels another is staring at him, noting his unruly hair, his wrinkled clothing, the weight he's put on. Worst of all, some persons insist on eye-to-eye contact! Auditory invasions may involve the incessant talker or the teenager with a transistor radio. Olfactory invasions may be mounted by the unwashed, the over perfumed, or the smoker.

Crowding is closely related to personal space. Usually, crowding is defined in terms of the ratio of people to available space, but Desor [77] has suggested instead that it be defined as "excessive stimulation from social sources." In that view, therefore, crowding can be reduced not only reducing the people-space ratio, but also by reducing the stimulation a person receives from others, even without alteration of the people-space ratio. Studies show, for example, that construction of partitions between people in a small space reduces feelings of crowdedness.

Research on the effects of crowding on human behavior and physiology is still in its infancy. Animal research has shown that excessive crowding over a period of years results in extreme stress, culminating in such negative effects as overactive adrenal functioning leading to adrenal collapse and death in deer [78], and gross pathology in sexual, aggressive, and maternal behavior in rats [79].

While it is extremely difficult to assess the relevance of long-term crowding on animals to short-term behavior of people on transportation systems, there is little doubt that crowding is aversive to most people and should be avoided in transportation systems whenever feasible.

A problem related to crowding on public transportation derives from the heterogeneity of groups of people using the system. Passengers may be of different ethnic and racial stocks, different age levels, and, to some extent, different socio-economic classes (although the lower class may be disproportionately represented). Much research has shown that people dislike and seek to avoid others who differ from them in such dimensions as socio-economic class, attitudes, and values [80, 81, 82]. Thus, the designer of a vehicle for intra-urban use should attempt to minimize the chances for social interaction.

However, there may be occasions when the presence of others on a public transit vehicle can be utilized to overcome the monotony of a long trip. A "group activity" can be arranged for those who are interested, in which passengers would interact in order to enjoy the travel time.

The new activity will vary from community to community, and from mode to mode. In some areas, square dancing on a vibrationless vehicle would be appropriate; in other areas, card playing would suffice. The

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popularity of the stand-up "bar coach" on some commuter trains attests to the popularity of structural social interaction in addition to the inebriating fringe benefits provided. In any case, travellers would be placed into a vehicle with a structured social goal. In addition to satisfying basic social needs, such a vehicle enables the user to avoid the stultifying monotony and boredom of the usual daily commute.

Significant obstacles to successful implementation of this plan exist. The previously mentioned tendency for people to avoid and dislike dissimilar others suggests that vehicles which draw a very heterogeneous riding population (e.g., the urban subway) would not be able to implement such a program due to passenger opposition.

In addition, a large amount of space is a requirement for most tasks involving social interaction; this would limit its use on buses. Therefore, commuter and inter-city rail transportation and airline travel would appear to be the existing modes that could best implement the concept of turning aggregates into groups. On commuter railroads, cars could be added at each station to the ongoing train, to ensure that the group participants in each car were homogeneous in socio-economic status, etc.

Finally, it should be stressed that not everyone wants to be part of a group all the time, or even any of the time. In addition, not everyone will enjoy the group activity. Therefore, it is essential to provide every traveller with the option or riding in a nongroup oriented cabin within the vehicle. Otherwise, one runs the risk of driving as many people off the vehicle as are attracted onto it.

2.3.3.2 Perceived Safety and Security

People are not willing to make many, if any, trade-offs against protection from personal harm. Thus, the risk of accident and the threat of crime are powerful factors in an individual's travel choices. While accidents and crimes do occur on transportation systems, their frequency of occurrence is, by most available evidence, not as great as people believe. However, what people **believe** is often more controlling than what actually takes place. In spite of the low accident rate on commercial aircraft, for example, many people will not fly simply out of fear based on news accounts of infrequent, but disastrous and highly-publicized airplane crashes. The President's Commission on Law Enforcement and Administration of Justice [83] found that the perception by people that public transport was crime-ridden had resulted in a drop-off in public transportation use. In some high-crime areas of Boston and Chicago, for example, almost one-fourth of the respondents to a Commission survey reported that they always used cars or taxis at night, rather than public transportation, because of fear of crime. Research by Misner and McDonald [84] revealed that less than one-half of one percent of the total number of passengers using public transit in Chicago were either victims of or witnesses to crimes. Yet, 70% of Chicago transit riders felt that crime was either "very likely" or "somewhat likely" to occur on mass transit vehicles. Furthermore, almost 25% of the Chicago passengers reported that they had not ridden a city bus out of concern for crime. Thus, attitudes and beliefs did appear to have a significant effect on behavior and travel choice.

What, then, might be done both to reduce actual crime and to change the public's perception that mass transit vehicles and stations are high crime areas? The need for research in this area is great. Misner and McDonald [84] have recommended some rather obvious steps, such as exact fare on buses, physical barriers between drivers and passengers, the use of paid riders as monitors on high-risk bus runs, and the use of cameras on low-traffic runs to record each boarding passenger. Alarm systems, two-way radios, weapons, tape recorders, and bus locators were **not** recommended. Improved driver training and selection, emphasizing interpersonal skills in dealing with the public, and intensive community relations efforts were strongly recommended.

2.3.3.3 Esthetics

Esthetics is often an after-thought in transportation design, neglecting the fact that esthetics involves an entire spectrum of experience for all of the human senses, over a broad band centered between the limits of psychophysical detection and levels of painful exposure. The fact that the experience is subjective and cultural makes it all the more important since the function of good design is to satisfy needs and desires. True satisfaction from the use of any system which is perceived through the five external senses rarely occurs without some degree of esthetic experience.

Esthetics are also important from the social and cultural point of view. "Our esthetic judgments are substantially modified by nonsensual data derived from social experience" [85] It is literally impossible to become involved with the design of transportation systems (including terminals, stations, rights-of-way, vehicles, and effects upon the nonuser) without altering the esthetic experiences of users, non-users, or both. The tremendous impact of transportation system and facility location upon the socio-economic and cultural stratification of communities has been witnessed for over a century. Status, political power, and zoning laws in a given area are influenced by the cultural and esthetic qualities associated with various modes of transportation. Phrases such as "beside the tracks," "a subway ride at night," "near the airport," or "ten minutes from the freeway" generate certain sets of social or cultural images in the reader. Favor or disfavor are the result, at least in part of esthetic effects generated by using or otherwise being affected by the modes suggested. **It cannot be over-emphasized that no new or improved transportation system, vehicle, or facility is likely to succeed in the engineering or economic sense unless it first satisfies certain social, cultural and esthetic values. The fact that such influences are difficult to define or measure does not negate their importance.** The designer of a terminal building or vehicle must recognize that people will be encapsulated within the structure. To this extent he is controlling the experience of the traveller. A visually attractive building with high levels of noise or odors can hardly be said to be esthetically pleasing. Total sensory perception is involved.

Experiments on color esthetics has revealed some dominant trends and tastes. Such experiments generally involve comparative tests using chromatic papers a few square inches in area. The extension of these experiments to tests in which subjects are enclosed by colored surfaces seems highly desirable. A review of 26 investigations involving over 21,000 observers found that the order of preference for six common colors was blue, red, green, violet, orange and yellow [86].

Some dominant trends in color preference as a function of age and experience with a product have been demonstrated [87]. For example, children's color preferences develop and shift with age, showing a tendency to move from warm to cool colors with increasing years. Also, pleasurable and unpleasurable experiences sometimes influence color preferences. Most color preference studies, however, cannot be accepted without qualification, particularly with respect to designing spaces which totally encapsulate the observer.

To summarize some of the major, basic considerations in choosing color, it should first be said that there appear to be few rules or research studies upon which to base the design of transportation buildings and vehicles. Architects probably know more about human reactions to color than researchers because of their constant exposure to subjective reactions under actual decision making conditions involving real surroundings and hardware. Second, there is evidence that blue and red are highly preferred as individual colors, but practically all studies upon which this conclusion is based have involved the comparison of small patches of color. Research on color preferences with regard to transportation facilities and vehicles is definitely needed. One fortunate aspect of the problem is that there seem to be few differences among races and nationalities regarding color preferences. Third, there are many methodological problems associated with research on color esthetics. Secondary reactions such as the experimental fatigue and boredom of subjects, after-images, and the situations under which colors are presented all influence color preference. Predictions of color preferences from an experiment are often highly dependent upon the conditions under which the results were obtained. Reliable esthetic "measures" or formulas have yet to be established. When they are, they should include effects of color harmony, conditions, form, size, complexity, and basic cultural reference of the subject and whatever he is viewing. The exploration of dynamic as well as static effects of color seems desirable when considering transportation systems.

In the architecture of vehicles and public buildings, patterns and arrangement (including overall internal design) can produce feelings of exhilaration, boredom, joy, depression, confidence and self-esteem, rejection and frustration, fatigue, and others. If there is any universal rule in providing patterns, it is: provide variation. The effect of patterns upon people who are in motion in a building should be considered also. Varied stimulation involving combinations of pleasing colors and shapes is necessary in achieving an esthetically stimulating effect.

The perception of fatigue in travelling (especially when walking in stations and terminals or along sidewalks) is largely influenced by the interesting variability of the surroundings. Walking two miles through a lighted brick or tile-walled tunnel is a totally different experience than walking two miles on the same type of surface through a park or museum. Modern architectural theory recognizes that such considerations are necessary in designing buildings and facilities. Similar comments apply to the internal design of vehicles. The psychological pattern effects created by old railway coaches and buses are far different from those experienced in modern airliners and high-speed trains, even though the number of square feet allocated to each passenger has not changed significantly. Patterns, like colors, help to establish the esthetic "atmosphere" of any man-made environment, including transportation.

Finally, it may be remarked that much more research on human subjective responses to the esthetics of surroundings is needed before definitive recommendations on these issues can be proposed with confidence to the designer.

2.3.3.4 Self-Esteem

Common sense, as well as research [88], tells us that human beings wish to think highly of themselves. Striving for high self-esteem is a pervasive, powerful learned drive. How does the experience of using a transportation system affect the user's image of himself? Unfortunately, public transportation in America today often works to lower the user's self-esteem.

Coopersmith [88] outlines four sources that give rise to high self-esteem: (1) the ability to influence and control others (power), (2) the acceptance, attention, and affection of others (significance), (3) adherence to moral and ethical standards (virtue) and, (4) successful performance in meeting demands for achievement (competence). All but virtue seem relevant to an examination of transportation's effect on self-esteem.

The individual's choice of transportation modes, and his vehicle choice within a mode, appear to be influenced rather strongly by considerations related to self-esteem. Clearly, the automobile, in the personal power, control, and freedom it imparts to the individual, often raises the self-esteem of the driver. Detroit has long been aware of this, of course, in its advertising which stresses looks and lines and quick acceleration. Automobile manufacturers are not alone. Airlines also seek to make the passenger feel important. The use of sexy hostesses, passenger control of lighting and seat adjustment, carpeted aisles, visually appealing interiors and exteriors are all designed, at least in part, to increase the passenger's self-esteem.

In deciding on their self-worth, people rely heavily on their perception of the opinions of others. Thus, if an airline conveys the impression that it thinks very highly of its passengers, it may well influence the passengers' own self-images. Since people want to think highly of themselves, the net effect is an increase in the number of passengers using the airline. Unfortunately, the reverse is true of much public transit. Dirty vehicles, lack of visually appealing exteriors and interiors, and the absence of amenities combine to make the passenger feel less significant, while the passenger's inability to control the vehicle's direction, destination and speed, as in a private automobile, or his lighting or chair tilt, as in an airplane, induces a feeling of powerlessness. The challenge to the designer in this are is to design a public transit vehicle or a new mode, such as the proposed PRT systems, that can compete with the automobile and the airplane in raising (or at least not lowering) the rider's feeling of self-worth. Certainly, as a start, stations and vehicles can be designed more attractively.

Although alteration of vehicle characteristics lies within the power of the designer, the problem of the influences of other passengers on the individual's self-esteem is more difficult. Festinger's theory of social comparison [89] states that people compare themselves with others in order to obtain most of the information they wish to know about themselves. Furthermore a person's most relevant comparison-persons are those who engage in activities similar to his own. If he perceives that everyone engaging in an activity with him is of a certain status, the inference that he, too, is of that status is difficult to avoid.

In most of our cities, public transit is used mainly by the poor, the young, the aged, and minority groups, those segments of the population that lack access to an automobile. Thus, riding the public transit in many cities is stigmatizing; people avoid transit to avoid being classified, by others or by themselves, as low in status.

It may well be that improvements to public transit, in terms of comfort, convenience, time, or cost may not result in increased ridership as long as the automobile driver perceives transit riders as being of low status. Massive advertising campaigns, however, may have some success in convincing people to use mass transit, **if** the new riders have pleasant experiences, in terms of comfort, convenience, time savings **and** a gain in self-esteem while on the vehicle.

2.3.3.5 Stress and Uncertainty

No public transportation system s appealing to its passengers if it subjects them to high levels of stress. Unpredictable schedules, missed connections, lost baggage, complex procedures, confusing routes through a terminal, long waits, uncertain service facilities, a lack of personnel to assist or give directions, and other difficulties increase passenger anxiety. The complications of travelling, especially for an aged or handicapped passenger, can be almost as stressful as motion sickness.

Robert White [90] has summarized the results of much research demonstrating the existence of a drive to master the environment, to become competent, in both animals and humans. Both exploratory behavior and curiosity are examples of this drive toward competence.

Uncertainty is a strong source of stress for the traveller for two reasons: it makes the individual feel incompetent in the situation, and, in addition, it makes attainment of his travelling goals more difficult. Foreigners using the Paris Metro have remarked with pleasure on the system of lighted route-location maps designed to help the subway user. To find out how to get to his destination, the treveller merely presses a button for his final stop, and the exact route then appears on the map in the form of lighted dots. No knowledge of French is necessary to use the system. Contrast this with many American systems which confuse natives and foreigners alike. There seems to be little doubt that both temporal or procedural uncertainty is stressful, and should be avoided. Prompt, courteous assistance from available informed personnel should be provided in terminals. Signs should be clear, utilizing drawings and figures to help the foreign traveller whenever possible. Messages should appear at points where passengers are likely to have to make decisions. Such measures should reduce the traveller's uncertainty, increase his sense of competence, and, ultimately, result in his selecting that mode of transportation more frequently.

How NOT to plan a highway (Mercury Blvd., in Hampton, Va.).

2.4 Impacts On The External Environment

2.4.1 Noise Pollution

2.4.1.1 Sources and Magnitudes

Noise is an inevitable by-product of transporting people or freight. There are substantial numbers of noise sources with which society must contend with such as the neighbor's air conditioner, the neighbor's lawn mower, and perhaps his children; but in the urban areas today the average ambient noise level is a result of the motor vehicle based transportation system [53]. This statement probably is true as well for large segments of rural areas of the nation which lie within a mile or so of one of the 40,000 miles of interstate highway.

The literature on noise in our urban areas and its effects on man is extensive. The best presentation of effects on man is given by Kryter [55] and in the conference results [54]. Noise generated by transportation activities is treated extensively in references [53] and [93]. Only a brief summary of key facts and concepts will be given here.

In section 2.3.3.1 there is a discussion of noise measurement scales. Consideration of noise pollution from transportation vehicles leads to questions of how sound intensity changes as it propagates through the air. Both the amplitude and the frequency content of a sound change as it propagates, but in the absence of significant obstructions the amplitude changes much more rapidly with

TABLE 2.14
WAYSIDE NOISE LEVELS AT 50 FT. FROM RAIL TRANSIT TRAINS ON AN AERIAL STRUCTURE

Speed	Single Rail Transit Car	2-Car Transit Train	8 to 10 Car Transit Train
70 mph	83-85 dB(A)	85-87 dB(A)	87-89 dB(A)
60	81-83	83-85	85-87
30	70-75	72-77	74-79

Subtract 2 to 3 dB(A) for Ballast & Tie Tracks

Source: [95]

TABLE 2.15
TYPICAL WAYSIDE NOISE LEVELS FOR SINGLE VEHICLES AT 50 FT. FROM THE LANE OF TRAVEL

Speed	Automobiles	Gasoline Trucks	Diesel Trucks
55-65 mph	75-82 dB(A)	—	—
55	—	78-88 dB(A)	84-92 dB(A)
25-35	60-70	70-80	80-88

Source: [95]

distance than the frequency. Propagation in tubes or other enclosures is drastically different. In free air the sound pressure level (rms pressure) can be expected to fall about 6 db when the distance from the source is doubled and the distances are several times the size of the source. There are many cases in which it may fall faster and a few in which it will fall more slowly due to large sources or reflections but this figure can serve as a useful rule of thumb.

Rudmore [57] gives a good introduction to the properties of sound and its measurement.

The magnitude of the sounds which are generated by various vehicles is indicated by Figure 2.28. Some typical variations are indicated by Figure 2.29 and Tables 2.14, 2.15 and 2.16.

The ambient noise levels are also of interest since in many urban areas it appears to be heading toward a critical level. Figure 2.30 indicates ambient noise levels in urban areas for three different population densities as a function of time. These noise levels are primarily functions of road traffic activity levels. Before leaving the presentation of

TABLE 2.16
NOISE LEVELS OBSERVED AT ABOUT 50 FT. FROM BUSES AND TRAINS

Motor Buses on City Streets	80-88 dB(A)
Passenger Train Engines	90-96 dB(A)
Passenger Train Cars	83-90 dB(A)
Freight Train Engines	92-94 dB(A)
Freight Train Cars	82-96 dB(A)

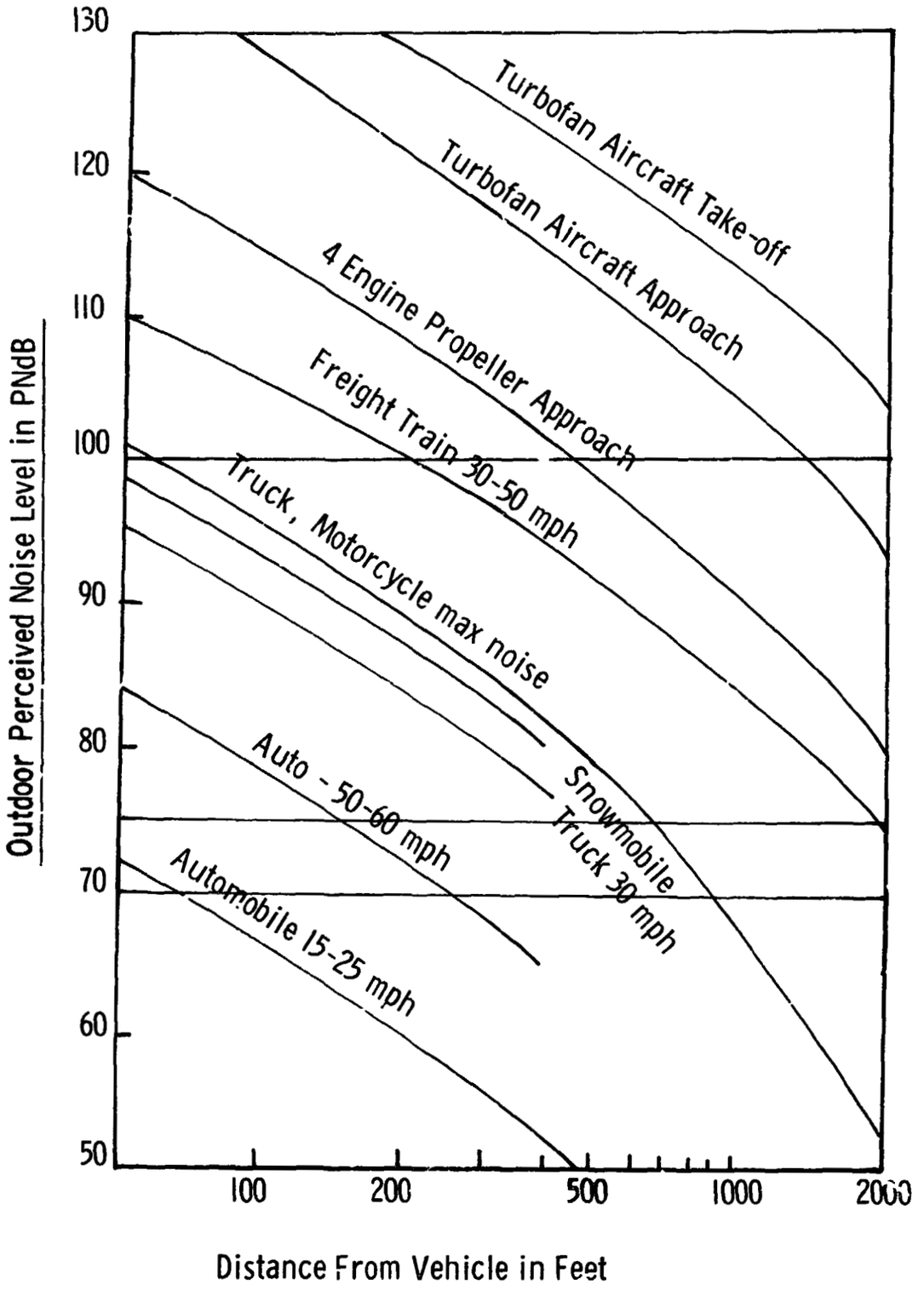
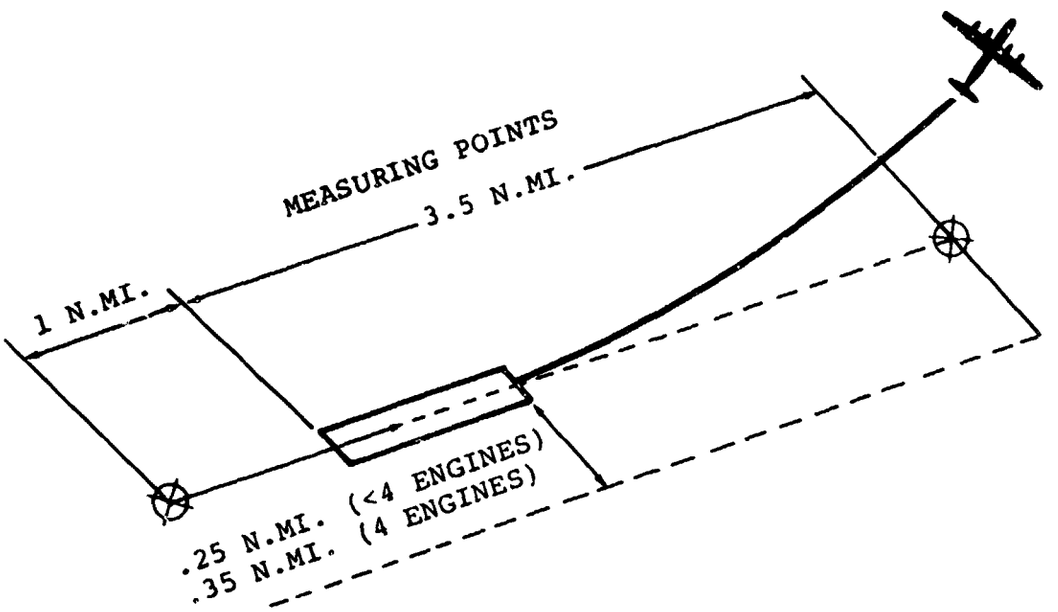


FIGURE 2.28
TYPICAL VEHICLE NOISE LEVELS



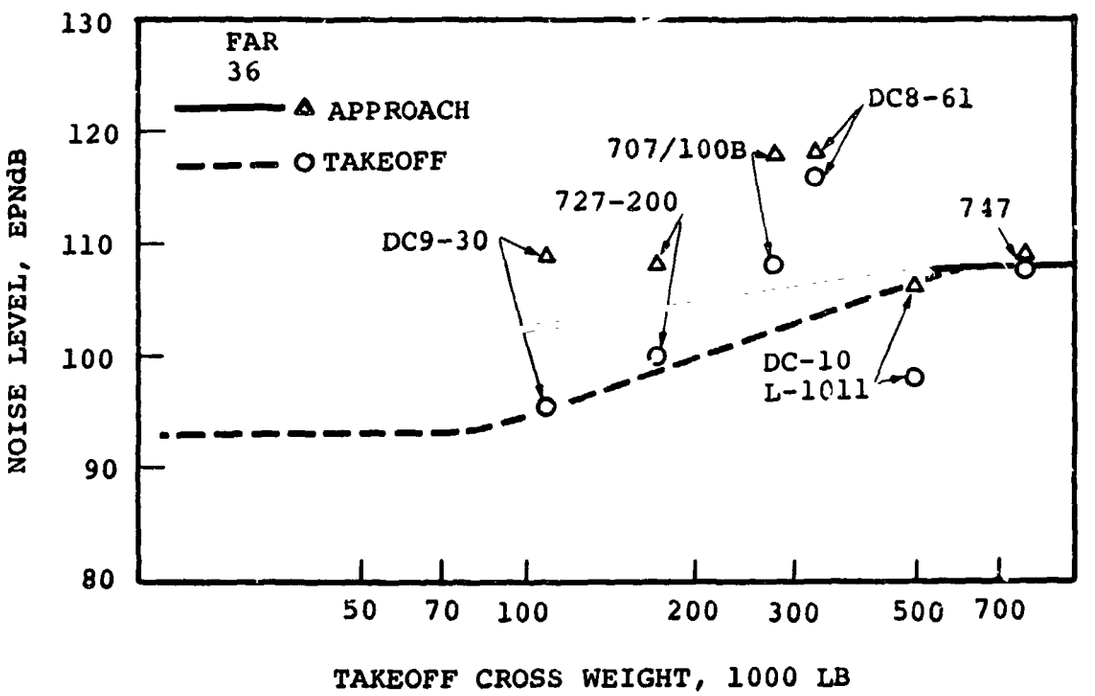


FIGURE 2.29
NOISE LEVELS OF CURRENT AIRCRAFT AT SPECIFIED MEASUREMENT POINTS

Source: [93]

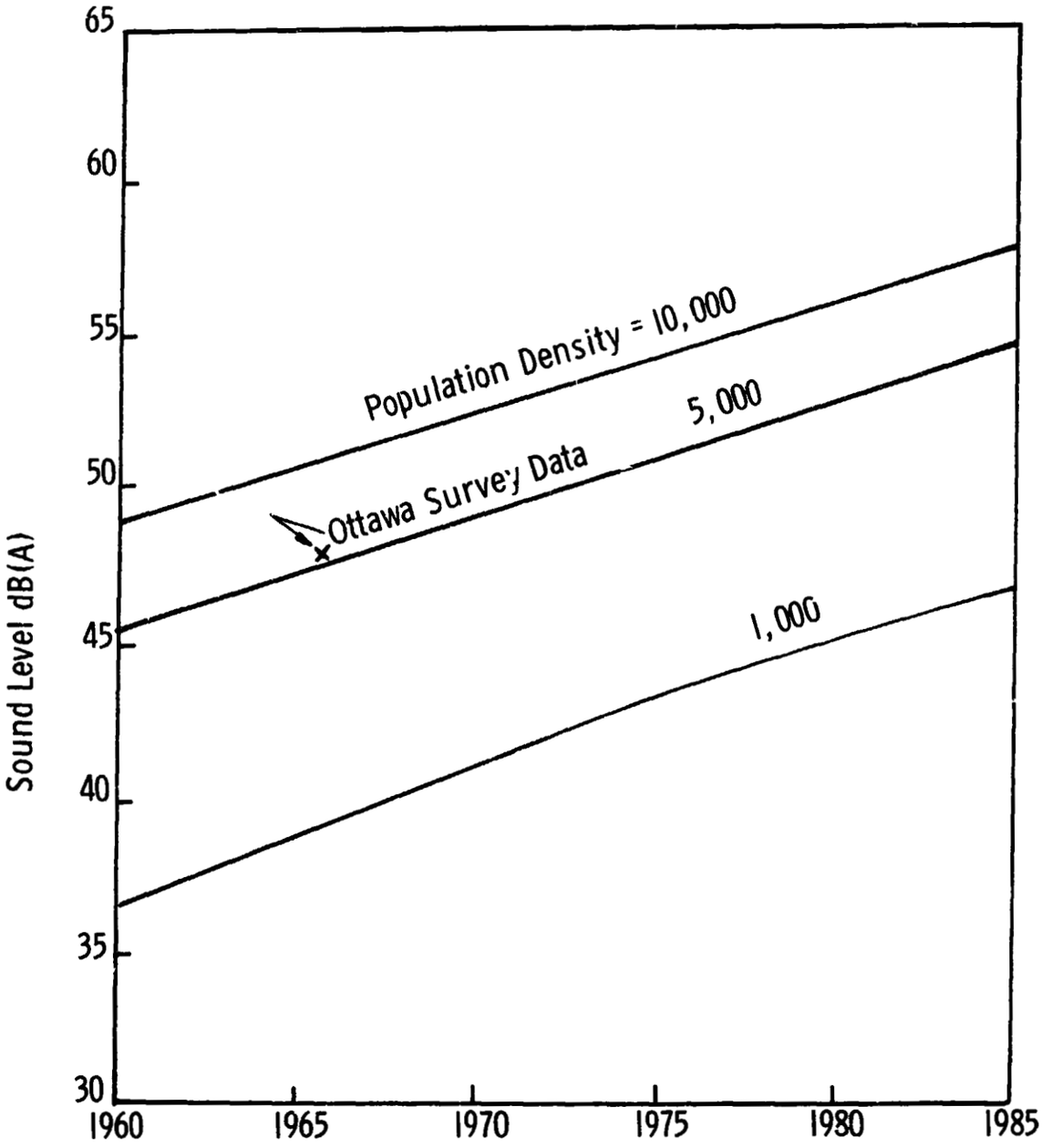


FIGURE 2.30
AMBIENT NOISE LEVEL FOR THREE DIFFERENT POPULATION DENSITIES
Source: [53]

magnitudes it will be useful to consider the variation in tire noise with tread design. Figure 2.31 shows that tread design alone can change truck noise by as much as 12 dbA. This is significant because trucks are responsible for a great part of the traffic noise difficulties.

2.4.1.2 Noise Exposure Criteria

In Section 2.3.3.1 there is a discussion of physiological effects of sound. Stemming from the fact that excessive exposure to loud noises can cause a decrease in hearing ability, there are industrial noise standards designed to minimize workers ear damage. In the case of transportation system noise, the regulations which exist have been adopted primarily as a result of protests from citizens after serious problems have developed.

With the exception of Alaska, all of the states and the District of Columbia have statutes or codes dealing with motor vehicle noise, i.e., appropriate sections of the Uniform Vehicle Code. With the exception of New York and California all of the states' statutes are qualitative in nature, e.g., "excessive" noise is prohibited or mufflers must be in good working order. Both the New York and California statutes set forth numeric sound level limits for motor vehicle operation; only California's statute is applicable to new motor vehicle sales. Under the California statute new motor vehicles cannot generate sound levels in excess of the following maximums, measured at 50 feet from the vehicle:

Motorcycles manufactured on or after January 1, 1970, and before January 1, 1973	88 dBA
Motorcycles manufactured after January 1, 1973	86 dBA
Motor vehicles with gross vehicle weight rating of 6000 pounds or more manufactured on or after January 1, 1968 and before January 1, 1973	88 dBA
Motor vehicles with gross vehicle weight rating of 6000 pounds or more manufactured on or after January 1, 1973	86 dBA

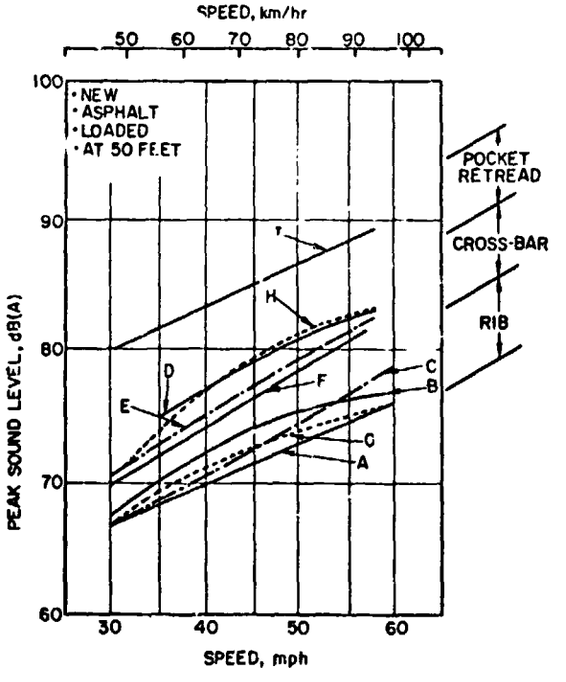


FIGURE 2.31

Peak A-weighted sound level, as measured at 50 feet, versus speed for a loaded single-chassis vehicle running on an asphalt surface. Various types of new tires were mounted on the drive axle. Letter designations for each curve correspond to the various tire types.

Source: [96]

Any other motor vehicle manufactured on or after January 1, 1968, and before January 1, 1973	86 dBA
Any other motor vehicle manufactured after January 1, 1973	84 dBA

Aircraft are now subject to two kinds of regulation. The FAA has specified noise limits which must be met to acquire certification of new aircraft. These limits are indicated on Figure 2.29. There are also local regulations at many airports which restrict operations at certain hours or demand special flight procedures. There has been developed a systematic procedure for estimating noise annoyance near airports. It is called the noise exposure forecast (NEF) As its name implies, the NEF is a tool to predict the future (as well as present) impact of aircraft noise on the surrounding community. Such information provides an invaluable aid in land-use planning and zoning around airports.

Because of the usefulness of the NEF, the FAA is preparing Noise Exposure Forecasts for a number of airports throughout the country. NEF areas consist of a map of a given airport and surrounding land with NEF contours—curves of constant NEF values—superimposed on it.

NEF contours consider a number of factors, including:

1. Effective perceived noise level, EPNdB
2. Number of daytime and nighttime operations.
3. Aircraft track and profile.

In general, the EPNdB value will vary from plane to plane depending upon type, and will, of course, also depend upon the distance between the observer and the aircraft.

Some important general conclusions concerning NEFs:

1. In general, NEF values decrease as the distance from an airport increases.
2. NEF areas may be divided into 3 more or less distinct regions:
   a. NEF less than 30—should be little annoyance due to aircraft noise.
   b. NEF greater than 40—could be considerable annoyance due to aircraft noise.
   c. NEF greater than 30 but less than 40—intermediate range.
3. If the number of operations at a given airport is doubled while all other variables are held constant, the NEF value at any given point increases by 3.
4. If the noise level per aircraft at a given airport increases by a given EPNdB, all other variables remaining constant, the NEF value at any given point also increases by the given EPNdB. The same is true for a given decrease in EPNdB.

Items 3 and 4 indicate that an NEF value, and hence annoyance, are far more sensitive to the noise levels of individual aircraft than to the number of airport operations. A simple example may help to clarify this point.

Suppose a person near an airport lives at a residence where the NEF value is 40. If the number of operations at the airport is doubled (a very significant increase), the NEF will, in turn, increase rather modestly to a value of 43. If on the other hand, at the original number of operations with NEF 40, the noise level of each aircraft is now reduced by 5 EPNdB (generally regarded to be a modest decrease), the new NEF value will be 35, which represents a significant decrease.

NEF areas for representative large and medium size airports are presented in Figures 2.32 and 2.33 for John F. Kennedy International and Raleigh-Durham (North Carolina) Airports for 1970 and 1975. At JFK Airport, there is very little difference between the 1970 and 1975 NEF contours, while the Raleigh-Durham Airport shows a substantial growth. The noise situation at some large airports, then, where the number of operations is reaching the saturation point, probably will not become significantly worse and, in some cases, may actually improve as new and quieter aircraft, such as the Boeing 747 and the jumbo tri-jets are introduced. The only new aircraft in design that will be noisier is the SST which is discussed later in this report.

On the other hand, the noise levels at small and medium size airports during the next 15 years can be expected to increase because of a significant increase in the number of operations and in the percentage of jet-powered aircraft, and (in some cases such as at Raleigh-Durham) an expansion of the airport itself.

The Department of Transportation has prepared computer programs to assist in preparation of NEF's. They are documented in reference 96.

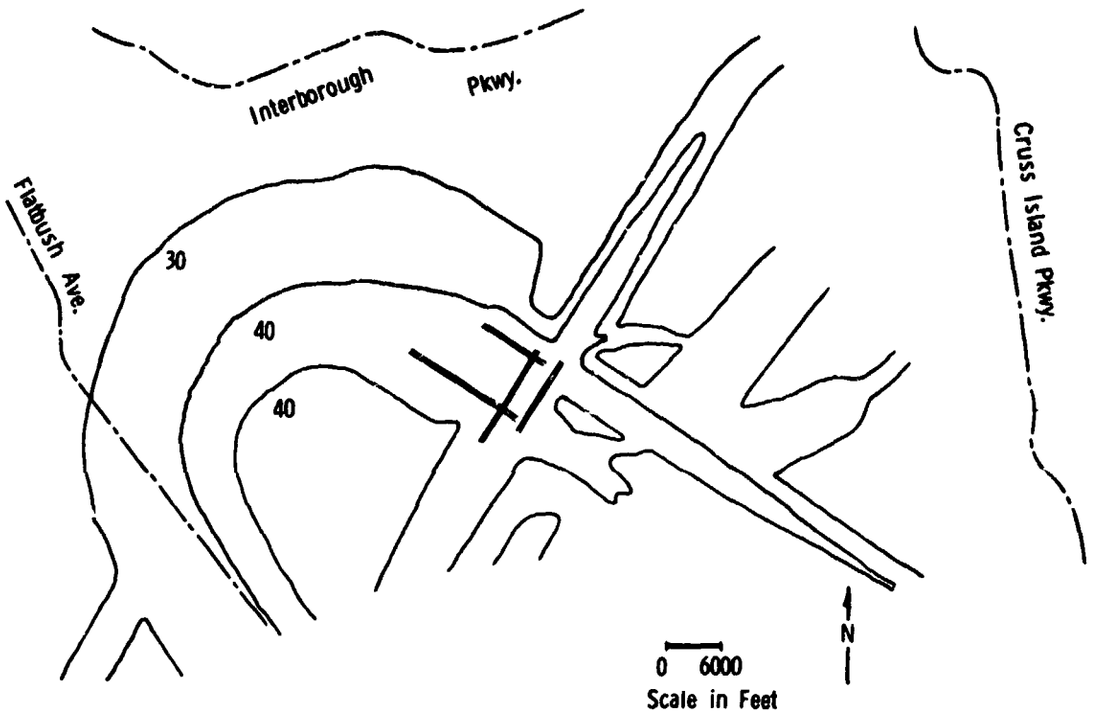


FIGURE 2.32
NOISE EXPOSURE FORECAST (NEF) CONTOURS FOR 1970 OPERATIONS AT JOHN F. KENNEDY INTERNATIONAL

Source: [53]

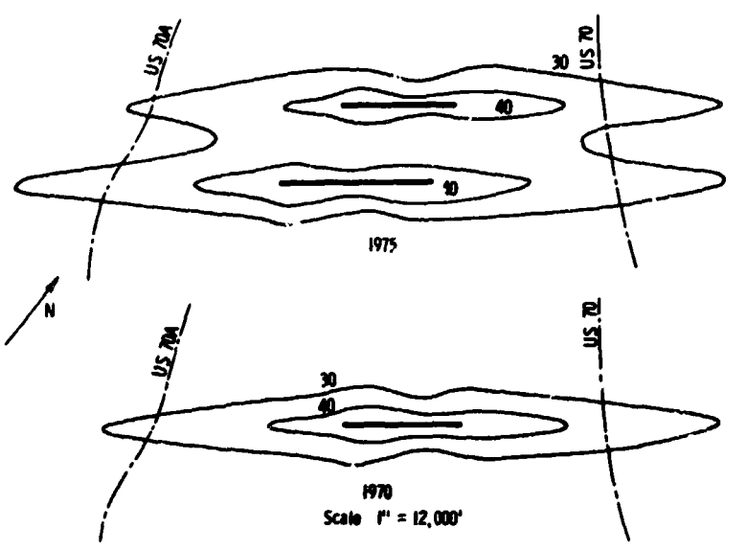


FIGURE 2.33
NOISE EXPOSURE FORECAST (NEF) CONTOURS FOR 1970 AND 1975 OPERATIONS AT RALEIGH-DURHAM (NORTH CAROLINA) AIRPORT

Source: [53]

It is significant to note that there have been no corresponding models developed for highway noise.

There are apparently no specific requirements to limit the noise from trains. Note from Figure 2.28 and Tables 2.14 and 2.16 that trains are a significant noise source It appears that they are not regulated because their rights of way have been established for long enough that people who would be annoyed have simply not moved near the tracks. It is curious that this effect does not seem to appear in the case of airports.

The annoyance perceived from various modes as indicated by citizen survey are shown by Table 2.17. it is evident that highways and airplanes are the greatest disturbers.

2.4.1.3 Steps Toward Relief and Control

Some steps toward control have already been cited in the form of the California motor vehicle regulations and the FAA noise certification standards. However, each of these is based on what appeared to be technologically feasible **to the industries involved** at the times of promulgation. These are steps in the right direction taken by particular parts of the governmental structure. However, it appears to us that a far more rational approach would be to determine the noise levels which are compatible with various types of land use, then promulgate equipment, system, and operating standards which will achieve the required levels. In many cases, this would require greatly expanded land use regulations, but it seems that there is no other way to achieve a complete solution.

Some basic questions of individual rights should be considered. For instance, should one be able to sit in his garden or on his patio and converse in a normal voice with someone at the other end of his picnic table? If so, then the noise levels must be limited to around 55db(A) or below (see section 2.3.3.1). Achievement of such a level around many urban residences demands separation from high

TABLE 2.17
SOURCES OF RESIDENTIAL NOISE ANNOYANCE SOCIAL SURVEY RESULTS

London Survey[1]		Tracor[2]	Chicago[3]	Chicago[4]	Minn.-St.P.[3]	4 Western Cities[4]	4 Eastern Cities[4]
Road Traffic	36%	Autos/Trucks	32%	22%	29%	22%	18%
		Motorcycles/ Hot Rods	36%	26%	26%	24%	33%
Aircraft	9%	Aircraft	37%	40%	33%	39%	62%
		Sonic Booms	12%	8%	13%	18%	16%
Trains	5%	Trains	7%	7%	3%	3%	3%
Bells/Alarms	3%	Sirens	8%	6%	15%	14%	17%
Industrial/Const.	7%	Construction	3%	2%	6%	2%	6%
Other People	19%	People Activities	33%	32%	32%	26%	20%
[Children]	[8%]	[Neighbor Children]	[18%]	[13%]	[13%]	[14%]	[9%]
Pets/Animals	3%	Dogs, Other Pets	10%	8%	13%	13%	15%
Number Surveyed	1,400	Number Surveyed	1,064	872	901	3,590	3,217

[1]/Noise Final Report [Wilson Report] 1963
Origins of external noise which disturb people at home-% of people questioned
[2]/Percent of respondents reporting upper two levels of annoyances for each noise source
[3]/Public reactions to sonic booms, 1969—General city areas and boom complainants
[4]/Community reaction to airport noise, 1970—Airport Environs only

speed highways and airports. In the case of the automobile, consideration of Table 2.18 which shows noise levels of 75 db(A) at freeway speeds seems to indicate that standards more stringent than the present California regulations might be technologically feasible.

The answers to the noise problems lie in the two areas of land use controls including noise zoning and continued technological attacks on the noise sources. Resolution will not be easy, but important first steps have been taken.

2.4.2 Air Pollution

[133]

2.4.21. Transportation and Air Pollution

The effects of the transportation modes on air pollution are well-known. The various modes of transport produce varying levels and types of air pollution. Table 2.19 indicates how much pollution is caused by transportation.

TABLE 2.18
AUTOMOBILE NOISE MEASUREMENTS BY VEHICLE MAKE AND ROADWAY TYPE

		1964 and Older			1965 and Newer		
		No. of Vehicles	Average (dBA)	Range (dBA)	No. of Vehicles	Average (dBA)	Range (dBA)
City Streets	(Under 35 MPH)						
	Chevrolets	[illegible]	68	60-84a/	1279	68	60-77
	Dodge	210	68	62-76	307	67	60-77
	Fords	883	68	61-76	1320	68	61-77
	Volkswagens	155	68	60-78	372	68	61-83a/
Country Roads	(Over 35 MPH)						
	Chevrolets	291	70	60-82	405	70	62-81
	Dodge	69	69	65-75	70	70	64-80
	Fords	109	70	63-81	433	70	62-83
	Volkswagens	37	71	65-83b/	102	71	63-84c/
Freeways	(Legal Limit)						
	Chevrolets	221	75	67-83	432	75	65-82
	Dodge	26	74	70-83	121	74	66-83
	Fords	141	74	68-84	530	74	64-87d/
	Volkswagens	62	74	66-95e/	196	75	68-83

NOTE Measurement distance 50 feet from center of lane nearest microphone, dry road surface, virtually no wind. Radius of 100 feet from microphone and vehicle kept clear of reflecting surfaces.

a/ Two vehicles exceeded 77 dBA. Both had modified exhaust systems.
b/ One vehicle exceeded 76 dBA. Had a modified exhaust system.
c/ One vehicle exceeded 82 dBA. Had a modified exhaust system.
d/ One vehicle exceeded 85 dBA. Had a modified exhaust system.
e/ One vehicle exceeded 81 dBA. Had no muffler.

Source: [93]

TABLE 2.19
ESTIMATED EMISSIONS OF AIR POLLUTANTS BY WEIGHT,[a] NATIONWIDE, 1969

Source	CO	Particulates	SO_x	HC	NO_x
Transportation	111.5	0.8	1.1	19.8	11.2
Fuel combustion in stationary sources	1.8	7.2	24.4	0.9	10.0
Industrial processes	12.0	14.4	7.5	5.5	0.2
Solid waste disposal	7.9	1.4	0.2	2.0	0.4
Miscellaneous	18.2	11.4	0.2	9.2	2.0
Total	151.4	35.2	33.4	37.4	23.8

a In millions of tons per year.

Figure 2.34 shows the relative air pollution contribution of these several modes. The figures are based on passenger-miles and they clearly show the automobile to be the worst polluter. Figures 2.35-2.38 show the diurnal variations of air pollutants for the urban areas of Detroit, Los Angeles, New York, and Cincinnati. A look at the peak hour pollution concentration suggests that the automobile contribution far overshadows stationary sources.

Given this pollution problem, it becomes necessary to control automobile emissions whenever possible. There are two main techniques used in the reduction of air pollution concentrations from automotive sources. These are reduction at the source such as alternative power sources and reduction of concentration.

2.1.2.2 Alternate Power Systems and Modifications

In order to meet the 1975-1976 standards, the automotive industry is concentrating its efforts on modification of the conventional combustion engine. The long term health and welfare needs of the nation cannot necessarily be met by the conventional engine. Therefore, the EPA has embarked on a program of federally funded research and development of alternative engine systems which are inherently cleaner than the conventional engine. This development activity is embodied in the Advanced Automotive Power System Program (AAPSP). When this program began in July of 1970 there were five types of power systems initially considered. These included Rankine cycle, the gas turbine, heat engine/electric hybrid, heat engine/flywheel hybrid, and all-electric. Two additional systems, the stratified charge engine and the advanced design diesel engine, have been added to the program. Limited privately sponsored research has been underway for some time on all of those systems.

Three types of Rankine systems are presently in the design and component test phase. The technical problems confronting the successful development of the Rankine cycle systems are understood and are being studied. Major problems appear to be in the inefficiency of components and the complexity of the control systems require. The first prototypes are expected to be available for testing in late 1972.

More work has been conducted by the domestic automobile manufacturers on the gas turbine engine than on any other candidate. Previously the gas turbine has been unattractive for use in automobiles particularly because they produce large amounts of nitrogen oxide emissions in the exhaust, they require the development of manufacturing techniques for mass producing turbines inexpensively, and they have not been very reliable in the past.

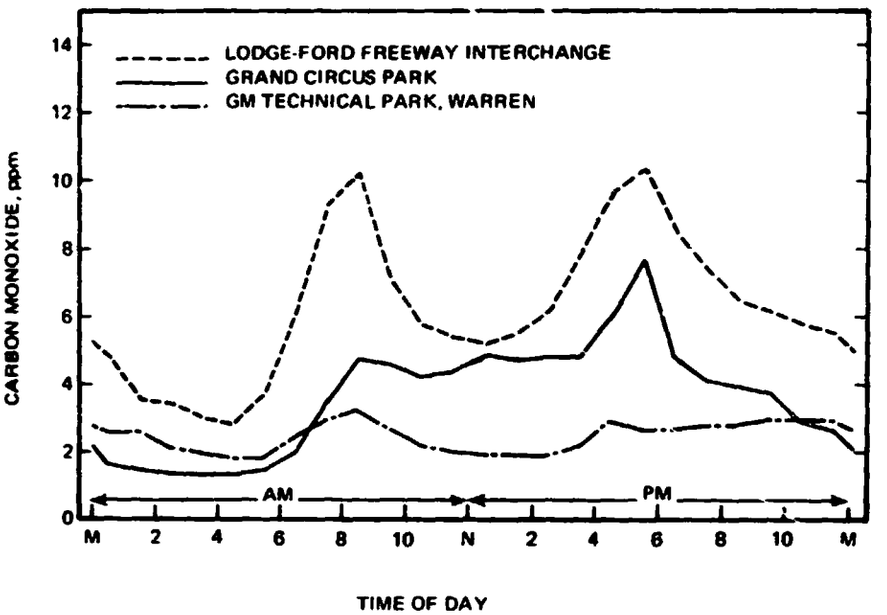


FIGURE 2.35
HOURLY CARBON MONOXIDE CONCENTRATIONS ON WEEKDAYS IN DETROIT AREA

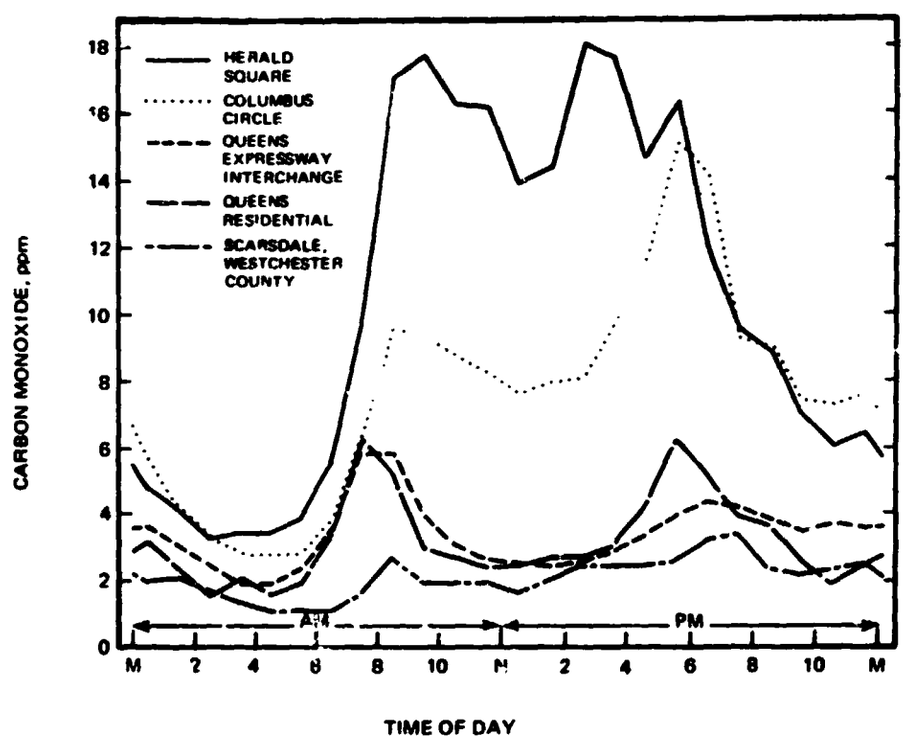


FIGURE 2.36
HOURLY CARBON MONOXIDE CONCENTRATIONS ON WEEKDAYS IN NEW YORK AREA

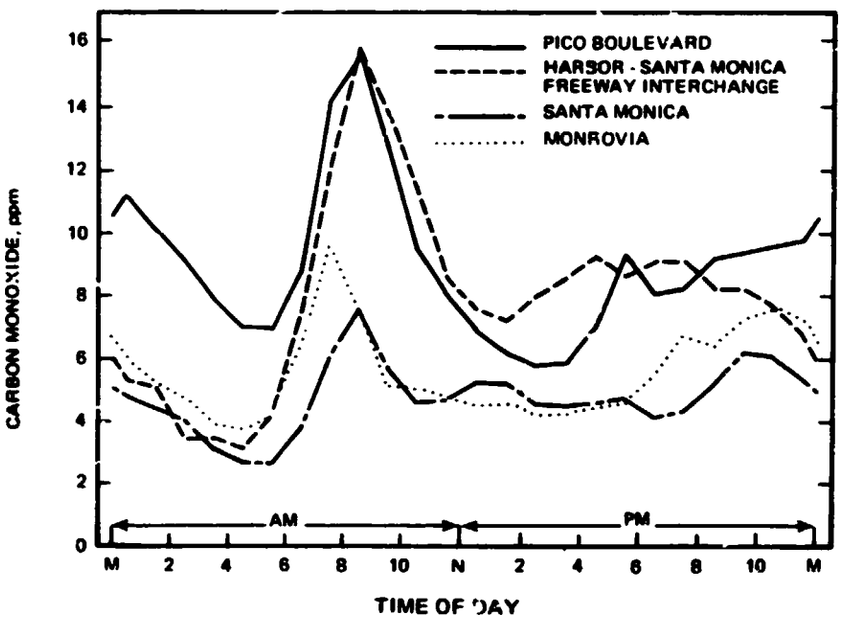


FIGURE 2.37
HOURLY CARBON MONOXIDE CONCENTRATIONS ON WEEKDAYS IN LOS ANGELES AREA

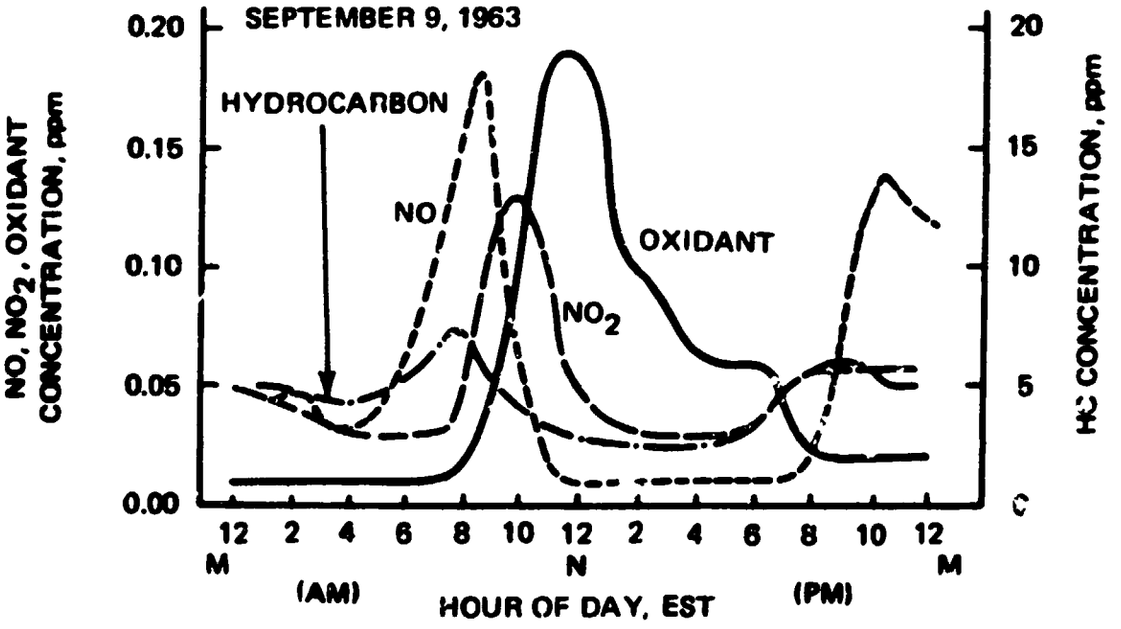


FIGURE 2.38
CONCENTRATIONS OF NITRIC OXIDE, NITROGEN DIOXIDE, HYDROCARBON, AND OXIDANT DURING A SMOGGY DAY IN CINCINNATI, OHIO

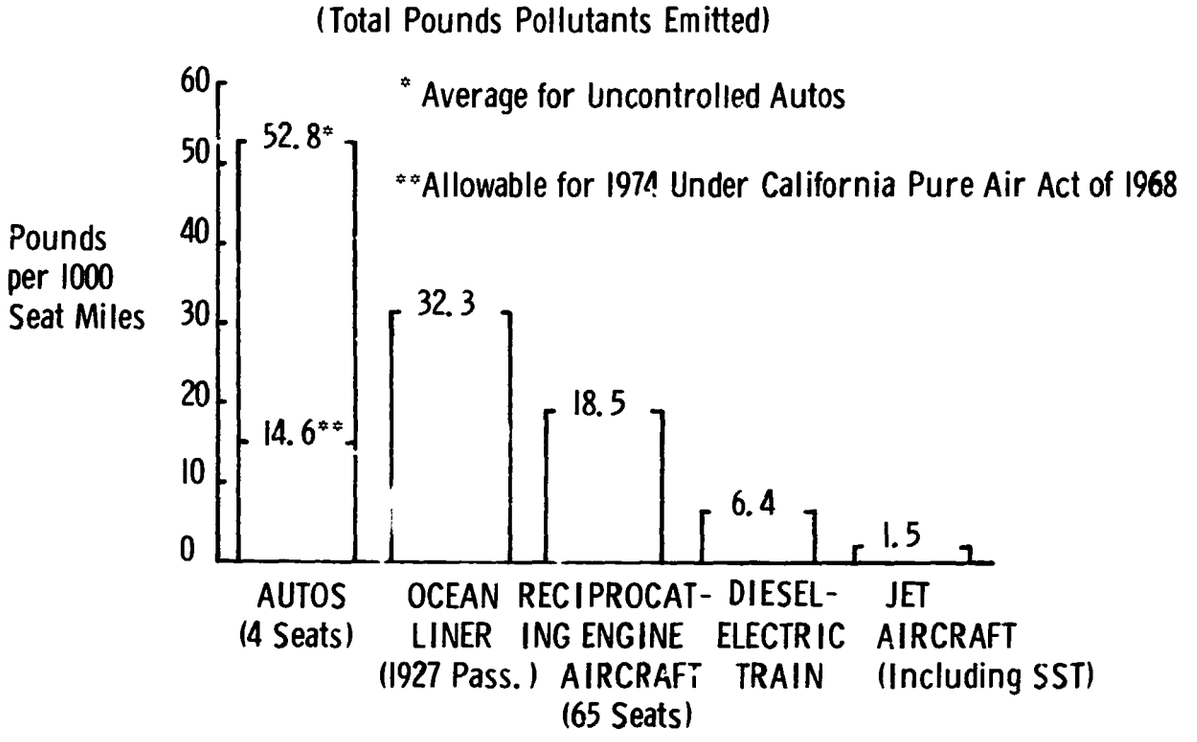


FIGURE 2.34
TRANSPORTATION AIR POLLUTION COMPARISON

The hybrid engine candidates include the heat engine/electric and the heat engine/flywheel. The hybrid concept offers the advantages of a low engine speed range with an attendant ease of control of exhaust emissions. Good road performance for a standard size automobile can be obtained with relatively smaller hybrid heat engine. The basic problems of the system are its relative complexity, higher cost, and greater space requirements. The heat engine/flywheel system has had as its stumbling block the progress of the design and fabrication of specific practical flywheels.

The all electric car engine development has been underway since about 1968 at Argonne National Laboratories. However, development of the all electric system will not be completed early enough to meet 1975 standards because the project is still in the fundamental research stage. Moreover, an environmental cost-benefit analysis is yet to be undertaken which would indicate whether there would be a net gain from the environmental viewpoint given the added burdens that such a system might place on electric power generation requirements. However, such a low emission vehicle might be highly desirable for congested urban areas.

The stratified charge engine is a gasoline fuel internal combustion engine with many hardware characteristics of a conventional engine. Differences appear mainly in the combustion chamber design and in the use of fuel ejection. The measured exhaust emission levels for an experimental stratified charge engine installed in a small military vehicle by the U.S. Army Tank Automotive Command and employing a catalytic muffler are below the standards for hydrocarbons and carbon monoxide set for 1975. Further work must be conducted to reduce the nitrogen oxide emissions to attain the 1976 standards. However, there are many problems to overcome to convert experimental engines to mass produced vehicles with similar emission characteristics.

The diesel engine is not commonly used in American made automobiles because it is heavier and more expensive than the con-

ventional automotive engine. Emphasis is being directed by the EPA towards a development of a low compression diesel with high swirl injection and a modified prechamger design. Exhaust emission levels for hydrocarbons and carbon monoxide lower than the 1975 standard have been shown for this type of engine without the need for a catalytic converter. However, additional studies need to be made concentrating on nitrogen oxide groups reduction, on performance durability, and drivability testing.

2.4.2.3. Auto Industry Progress

The gasoline fueled internal combustion engine is the best understood and most reliable propulsion system currently available. In order to meet the standards set up for 1975-76 automobile, the auto industry maintains that the internal combustion engine is the only prospect for mass production Unfortunately, it is also an inherently high emissions propulsion system. To a major degree the high emissions are caused by the fuel itself and to the difficulty in supplying each cylinder of the automobile with the proper thermodynamically ideal air and fuel charge in order to bring about the complete combustion over the full range of vehicle operating requirements. Normally, efforts aimed at reducing hydro-carbons and carbon monoxide tend to increase emissions of nitrogen oxides. On the other hand, the control of nitrogen oxides to high levels within the engine tend to negate the improvements gained in HC and CO control. Thus, NOx control will probably require other measures to reduce peak combustion chamber temperatures and/or the addition of an external control system.

2.4.2.4. Typical Control Concepts and Devices

Engine modifications designed to reduce emissions during the combustion process now represent the principle approach used by the auto manufacturers in order to comply with the motor vehicle exhaust emissions standards now in effect. Such modifications are normally aimed at reducing the emissions by a more efficient combustion process. In addition, add on devices such as thermal reactors and catalytic converters will most likely be required in order to complete the system modifying gasoline composition, such as the elimination of lead and possibly changes in fuel volatility characteristics, may also be required in order to facilitate the use of certain control techniques and optimize the potential of others.

2.4.3 Air Pollution Reduction Through Traffic Control

In addition to attempting to control air pollution at the source, such as air pollution emissions standards, it seems realistic to try to control the air pollution through the reduction of traffic. In simplified terms, the emission of the principal pollutants related to urban vehicles, that is carbon monoxide and hydrocarbons, increases as average speed decreases, and decreases as average speed increases. There is some evidence that the reverse is true for the oxides of nitrogen. Table 2.20 based on a 1967 British report [135] indicates a relationship between vehicle operation and the level of pollutant emission. These emissions are from uncontrolled autos. Table 2.21 shows the extent to which emissions have been controlled since 1960.

TABLE 2.20
TYPICAL LEVELS OF CONCENTRATION OF POLLUTANTS IN EXHAUST GASES

Pollutant	Idling	Accelerating	Cruising	Decelerating
Carbon monoxide, % by volume	7.0	3.0	4.0	3.0
Hydrocarbons, ppm	820	700	500	4,400
Oxides of nitrogen, ppm	30	1,050	650	20

TABLE 2.21
EMISSION FACTORS[a] FOR GASOLINE POWERED MOTOR VEHICLES

Emissions	1960	1965	1970	1972	1974	1975
Carbon Monoxide	120	120	95	85	75	60
Hydrocarbons						
Evaporation	2.7	2.7	2.7	2.3	1.8	1.4
Crankcase	4.1	2.7	0.9	0.45	0.22	0.22
Exhausts	16	16	12	9.5	7.2	6
Nitrogen Oxides (NO_2)	8	8.5	9	9	7.5	7

[a] Grams per vehicle mile at 25 mph.

Another study [136] indicates a direct correlation between increased average vehicle speed and decreased emission of carbon monoxide and hydrocarbons. If the objective is to minimize the concentrations of carbon monoxide and hydro-carbons, any measure would be beneficial which would smooth the flow of traffic by reducing rapid acceleration and deceleration of vehicles. However, easing congestion may have ancillary effects that would tend to undermine the goal of cleaner air. The relationship between increased travel speed and increased trip demand has been well established [136]. Furthermore, a reduction in congestion may tend to induce more people to drive. Instead of having reduced the auto pollution, the net result of increased traffic flow might be more, longer, and more dispersed trips with greater amounts of pollutants spread wider areas.

2.4.4. Techniques For Reducing Pollution Concentration

[137]

The design and utilization of highways can be effective in reducing the air pollution concentration in the ambient air. The techniques that have proven successful in recent times have been:

1. staggered work hours
2. roadway concentration studies
3. cross-sectional roadway variations
4. elevated, at-grade, depressed roadways

A. Staggered Work Hours

Staggered work hours were first used in the United States during WW-II when approximately 60 cities used the idea to alleviate the critical problem of mass transportation capacity shortage. At that time, many cities reduced travel demand by as much as 30%. However, all major staggered hour plans were terminated after the War. Staggered work hours should spread the demand for travel over a long time period, thereby reducing the magnitude of the peak period demand.

Staggering the morning rush is particularly important because the wind speed early in the day is low and the atmosphere is generally very stable—conditions that inhibit the dispersion of pollutants. It has been estimated that delaying the morning rush hour in Los Angeles by one hour would reduce oxidant (smog) concentrations by 24%. The most publicized plan for staggered work hours in recent years [138] has been in lower Manhattan area of New York City where in 1970, about 50,000 persons began a program of staggered work hours, shifting from the traditional 9:00-5:00 schedule. As of April, 1971 there were about 60,000 people representing 70 private firms and governmental agencies on the new schedule [139].

A significantly changed pattern in peaking characteristics was evidenced as a result of the staggered work hours project and is seen in the Hudson Terminal Afternoon Passenger Volumes but the percentage of workers on these staggered hours was insufficient to show a reduction in air pollution.

B. Roadway Concentrations

A number of studies have been made of the air pollution distribution patterns (both vertically and horizontally) from roadways to understand the effects of highways on pollution in adjacent buildings. The German city [140], Frankfurt-am-Main, was the subject of an investigation on the time and space distribution of carbon monoxide emission concentrations. Figure 2.39 shows the CO concentrations on both the leeward and windward sides of the roadway at heights of 2, 16, and 33 meters above the roadway. [140]

In addition to vertical height, it would be very important in locating structures near a highway if one could determine how close to the highway the building could be constructed in order to maintain a safe, acceptable pollution level. Figures 2.40 and 2.41 show the pollution level vs. the distance to the edge of the roadway [141]. In addition, a study was made of the concentrations of CO resulting from vehicles elevated above the roadway. The lines of equal value of concentrations of carbon monoxide (isopleths) are shown in Figure 2.42. The ambient level was presumed to be 0 feet. Emissions are a function of vehicular elevation and horizontal distance from the edge of the roadway in feet.

C. Cross-Sections

Concentrations of nitrogen oxide, hydrocarbons, and carbon monoxide were measured at various levels above 5 different types of highways, including an expressway with adjacent structures nearby, an expressway without these joint structures and an expressway boulevard.

A highway without joint development structures may have a 26% reduction in carbon monoxide concentrations.

D. Elevated, At-Grade, Depressed Roadways

The decision to design a new highway as an elevated, at-grade, or depressed facility can have a major effect on its air pollution impact. In this respect, the reduction of neighborhood disruption and noise comes head-to-head with the reduction of air pollutants. A depressed highway in urban areas usually reduces neighborhood noise; but this type of highway affords little opportunity for local wind currents to disperse the emissions. Thus, the motorist travelling on a depressed highway, as well as persons in adjacent areas, may be exposed to unusually high air pollutant concentrations. On the other hand, elevated highways are more exposed to wind currents, which transport as well as disperse pollutants. These highways promote rapid dispersal of pollutants away from the motorists which may be a positive benefit for the motorist but which may not benefit the adjacent areas. If the pollutants are taken away from the highway but are transported into an adjacent building, the overall effect is very undesirable. In this regard, the highway designer might do well to consult with local meteorologists before he designs his elevated corridor.

2.4.5 Aircraft Air Pollution

Relatively little attention was given to aircraft air pollution until the late 1950's when turbojet aircraft were introduced as commercial air carriers. The turbojets emitted highly visible exhaust plumes. The density and odor of these plumes prompted demands for reductions of jet aircraft emissions.

Early studies of aircraft air pollution were undertaken by Los Angeles County Air Pollution Control District (LACAPCD) [142] 1960 and by the Coordinating Research Council [143] but the results showed that at that time total contaminant emissions were insufficient to produce a degradation of air quality or any property damage. In 1965 LACAPCD [144] undertook a second study, including piston engine aircraft, and showed a substantially higher percentage of total emissions attributed to aircraft. The 1965 study showed that aircraft were responsible for about 1-2 percent of all organic gases, carbon monoxide, and oxides of nitrogen in Los Angeles County and about 10 percent of all particulates.

The greatest single reduction in aircraft emissions was the introduction of jet service by the airlines in 1958. The early turbojet engines cut in half the emissions per engine during a typical airport operation Counting landing, taxi, takeoff, and all other operations under 3000 feet, the piston engine of a long-haul pre-1958 airlines produced 111.6 lbs. of emissions. [145]. The jet that replaced it produced only 55.2 lbs. per engine—despite the fact that it belched smoke when using water injection for takeoff.

Each new jet engine put into service thereafter has brought a further reduction in emissions. When the fan jet began flying in 1961, it brought the pounds of emissions per

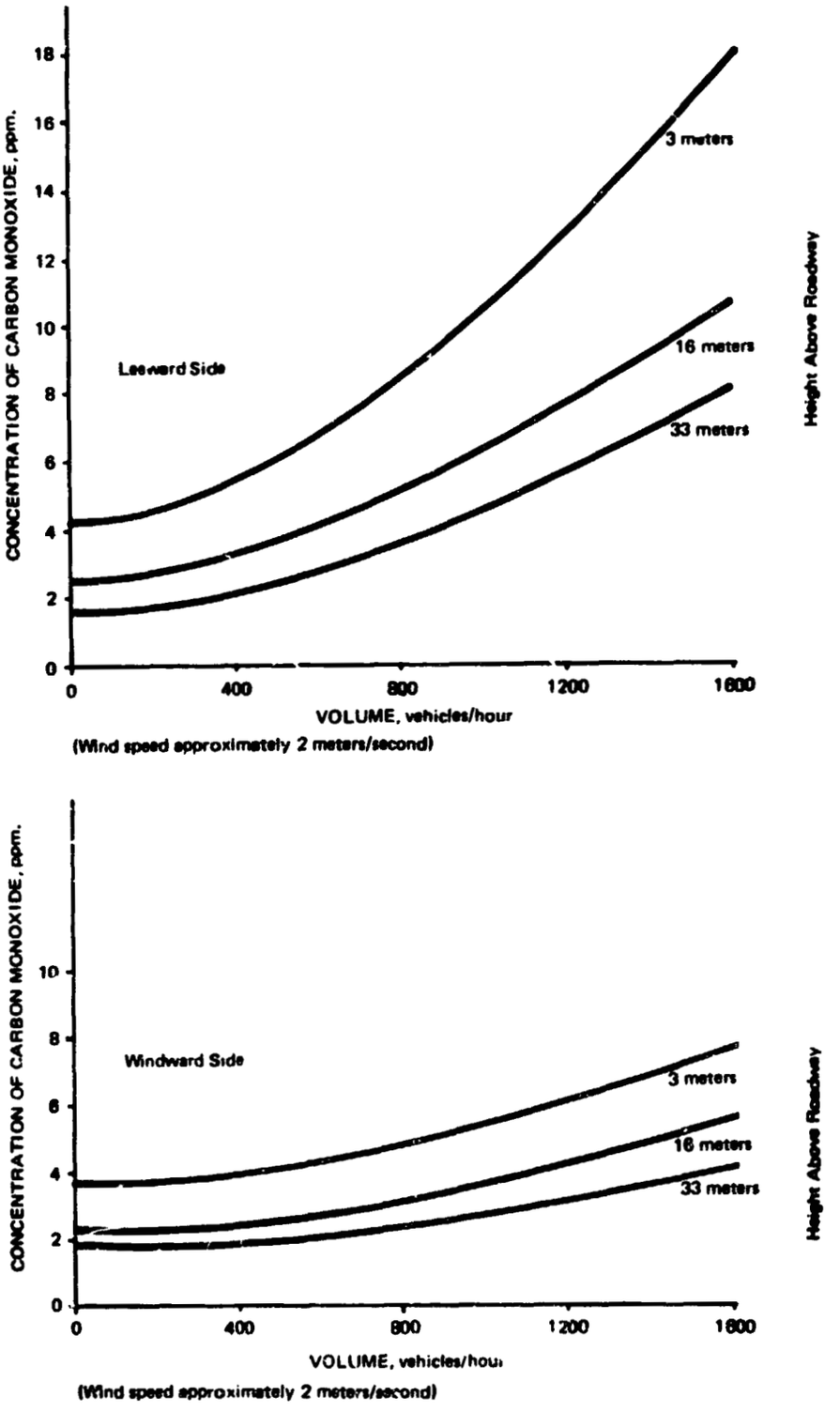


FIGURE 2.39
CARBON MONOXIDE CONCENTRATIONS DEPENDING UPON TRAFFIC VOLUMES

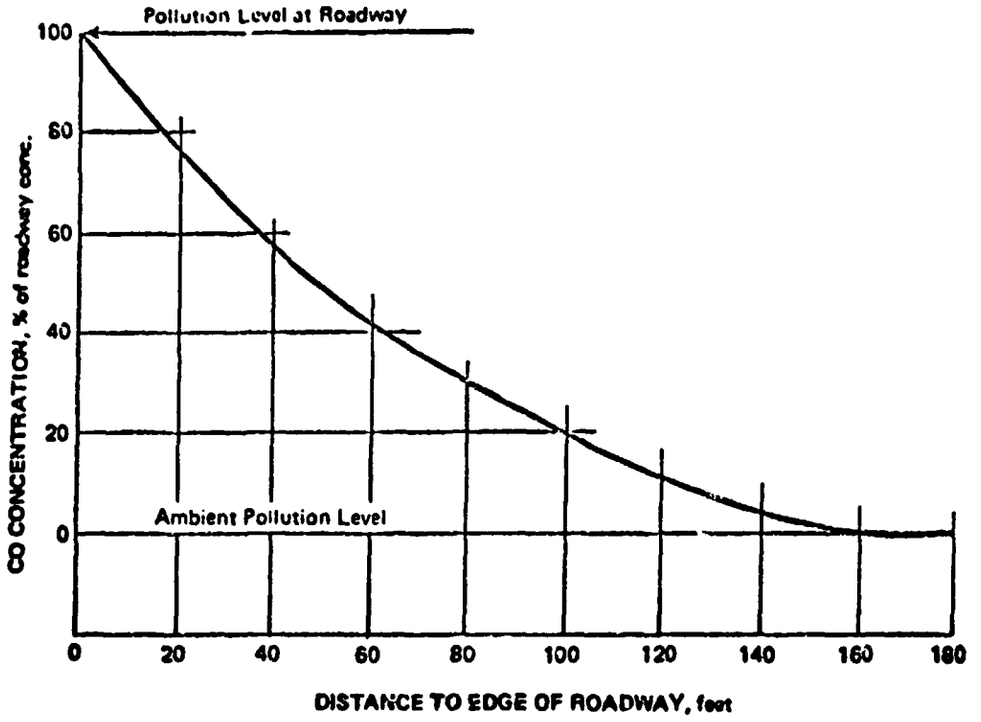


FIGURE 2.40
POLLUTION LEVEL VERSUS DISTANCE TO EDGE OF ROADWAY

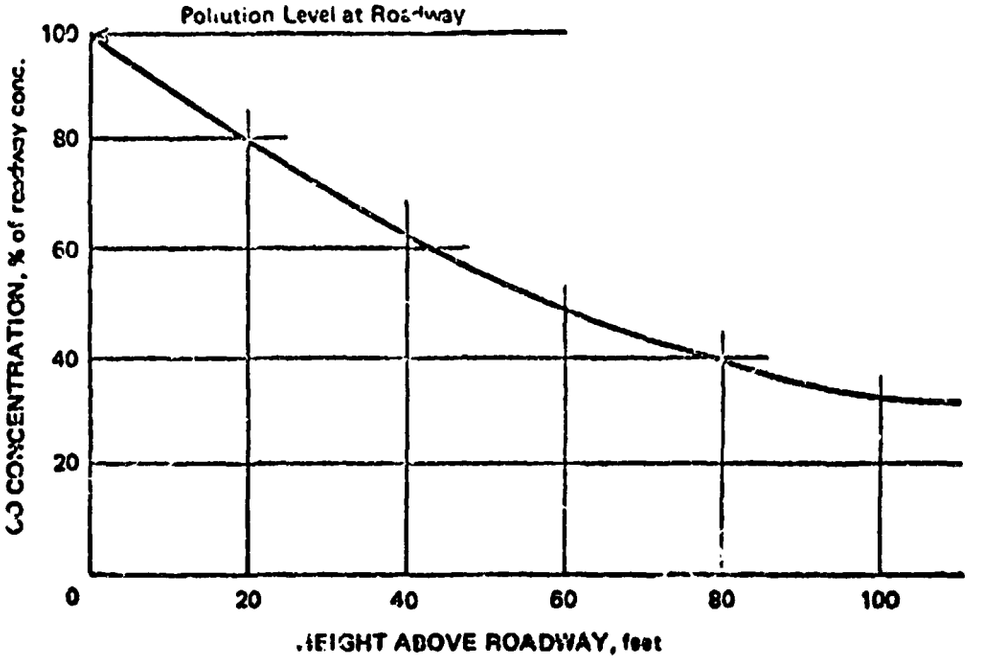
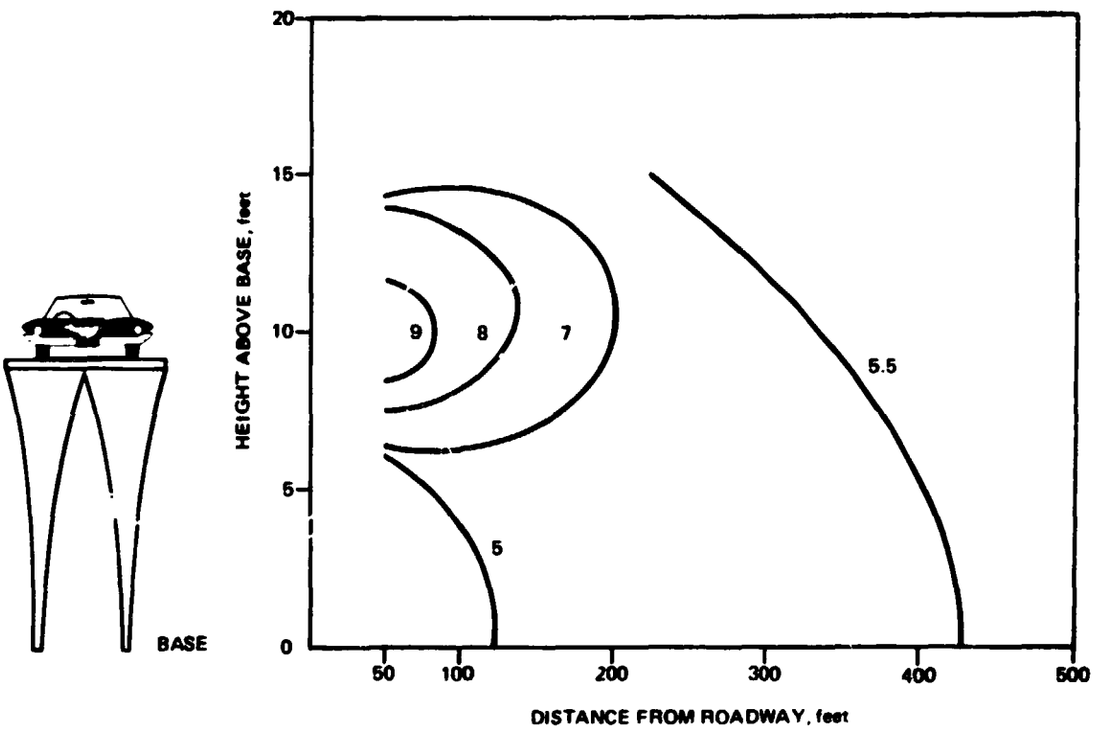


FIGURE 2.41
POLLUTION LEVEL VERSUS HEIGHT ABOVE ROADWAY



NOTE: Lines shown on this diagram are isopleths for carbon monoxide concentrations (parts per million as shown).

FIGURE 2.42
CARBON MONOXIDE CONCENTRATIONS FOR A HIGHWAY DESIGN

engine down to 49.1 for the same airport operation. In 1971, the JT9-D engine that powers the Boeing 747 has reduced the emissions during the airport operation to 33.5 lbs. per engine. From the earliest Boeing 707's to today's giant 747, jet engine horsepower has increased 1,400 percent. Yet the emissions per engine have been cut slightly more than 38 percent!

The smoke seen trailing behind jet engines is made up of small particles of unburned carbon. The carbon is formed by incomplete combustion of very small amounts of jet fuel. The particulates represent a very tiny portion of the total emissions per engine—the highest being half of one percent of total emissions per engine. Even the blackest smoke plume—that from the JT8-D

TABLE 2.22
AIRCRAFT EMISSIONS BY ENGINE TYPES
(DURING TAKE-OFF AND LANDING)

	Pounds of Emissions per Engine	Pounds of Emissions per Psgr. Carried*
1. Piston engines	111.6	14.88
2. Jet engines 1958	55.2	3.56
3. Fan jets 1961	49.1	3.16
4. IT9D engines 1970	33.5	.6979

*Assumes 50% load factor for each aircraft type

engine—is produced by particulates that represent less than two-tenths of one percent of the total emissions, or 0.42 lbs. per engine out of a total of 25 lbs. per engine per airport operation. The airlines have long recognized that jet smoke plumes should be eliminated. All new aircraft, beginning with the wide-bodied Boeing 747, are being delivered with engines that are virtually smoke-free. The cause of smoke emission was determined to be the result of small fuel-rich pockets of combustion in the forward end of the combustor itself. Through redesign of the manner in which the fuel and air are introduced and mixed in this area, significant reductions in the amount of smoke emitted can be accomplished. For one engine in particular, that powering the Boeing 727, 737 and McDonnell-Douglas DC-9, these redesign efforts were culminated in a modified combustor. This modification began to be voluntarily incorporated by the airlines early last year. It is expected that the modification program will be substantially complete by the end of next year and will have involved about 3000 engines, each with nine combustors. The result of this modification has changed these aircraft from being the worst offenders by their very dark exhausts to aircraft with practically invisible exhaust trails.

2.5 Summary and Conclusions

It has been the purpose of this chapter to describe the primary physiological and psychological factors that influence people's choice of transportation modes and dictate their comfort. It should also be clear that throughout this fabric of human considerations in transportation run dominant threads of economic, political, social, and institutional character. The pattern formed by those factors will now be developed in Chapter 3.

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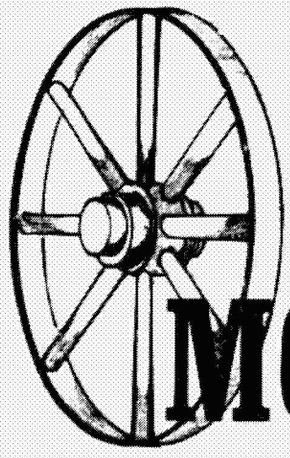

MOBILITY and SOCIETY

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Introduction

In its recent report on the budget for the Department of Transportation, and related agencies, the House of Representatives Committee on Appropriations observed that

> Transportation is a vital factor in the economic-social welfare and growth of the nation. What America has become, in many ways, can be attributed to the development of its transportation system. [1]

What has our nation become? A New York City architect, Percival Goodman, recently gave this description of our cities:

> The smog hangs heavy in metropolis; the streets are filthy; breakdowns in transport are daily; the welfare rolls grow; housing stock declines; and rents soar, as do the costs of other necessities. The parks are filled with broken glass and like the quiet streets, are avoided, as the crime rate soars. The sewers pour their untreated wastes into the rivers, and the garbage piles grow. The cities, already swollen into metropolises, swell further into megalopolises, gigantic machines used, if not designed, for dead end operations. Man's ingenuity, which once filled him with pride, now causes dismay, as each day new ways are found for ransacking or poisoning continents and their enveloping seas. What had been a symbiotic relationship between man and nature, a continuous recycling, has been transformed into a consumer relationship, whereby man is consuming not merely his interest, but his environmental capital. Nowhere is this devastation more apparent, or more cause for alarm, than in the nation's cities. [2]

In a broader context, Mr. Goodman further stated:

> The time has been reached when society's basic institution, capitalism, has begun to consume irreplacably its basic resource—the environment. For too long man has forgotten, if in fact he ever knew, that ecology and economy are two inseparably linked phenomena, one dealing with the relationship of living things to their environment, the other with the management of the products contained in the environment. The engineers of today's economy have not attempted to balance these concepts. When the need to revitalize the cities was first realized, flight to the suburbs was encouraged by the financing of new homes and even new subdivisions. The government then subsidized a transportation program that requires private means—a car—for its utilization, without making any provision for those not sufficiently affluent to afford such means. Nevertheless, even as the danger of air pollution in the cities is beginning to be recognized, superhighways are still being constructed to encourage people to drive into the cities. The economy's insensitivity to the impact of its actions has resulted in an ever-widening gap between the decay of society and the ability to prevent it, much less eradicate it.
>
> It cannot be said, of course, that the economy is completely unplanned, but the semi-planned approach being used has serious deficiencies. For example, the obsolescence of products is planned in order to insure a continuing consumer demand; a method has not been devised, however, for disposal of such products once they reach obsolescence. In the cities, boundaries are planned, but again no effective method has been planned for changing these boundaries once they become obsolete. Such actions, as well as countless others, have contributed to the demise of the environment and the inability of governmental structures to cope with the problem. In short, there has been a failure to take cognizance of the externalities of the nation's development, and past history casts a foreboding light on a future already indebted to the environment by today's "borrowing." [2, pp. 671-672]

These words raise serious, but not unfamiliar questions. Current projections indicate that by 1990 our population will have increased by 50 million over the 1970 census figure to 253 million. [3] What will our cities,

and our nation as a whole, be like then? Will we plan for our future development? Will transportation be used in a positive way to foster proper land use and desirable social and economic development?

We have the technological capacity to solve transportation problems. These solutions do not all require exotic new vehicles or modes of transportation. Federal funds are available for bicycle ways built in conjunction with highways. The Department of Transportation is strongly supporting their use for commuting and recreation. [4] At the other end of the spectrum, the Department of Transportation is experimenting with a tracked air cushion vehicle designed for speeds up to 300 miles per hour, and studying tunnel vehicles with anticipated speeds to 500 miles per hour.

We have a balance of existing and new technology with which to work. However, technology is merely potential until a decision is made to use it. The policies and decisions which control the use of technology are made within a political framework. Many competing social and economic interests must be considered. We believe that there are more barriers to effective transportation planning in this decision-making process than there are in the area of technology.

This chapter focuses on the institutional framework in which transportation policies and decisions are made, national transportation policy, and **social and economic aspects of mobility**. It deals with problems which are easy to identify, but very difficult to solve. The problems are difficult to solve because they involve people and their conceptions, misconceptions, prejudices, and stubborn resistance to change. However, they are problems which must be faced squarely.

The Institutional Framework for Transportation Policy and Decision-Making

Transportation policy decision-making in American society is, indeed, a complex and highly diffused process. A whole proliferation of individuals in authoritative positions and political institutions from the federal government, to the fifty state governments, to the hundreds of thousands of local governments is directly involved in significant decisions which relate to the movement of people. Moreover, the number of non-governmental vested interest groups which participate, or at least attempt to participate, in transportation decisions is certainly extensive.

The Federal Level

All three branches of the federal government are actively involved in matters relating to transportation. While decision-making in the area is a highly involved and complex process, each branch can be examined in terms of its general level and type of responsibility for transportation policy in the United States. True, to analyze the process according to a branch by branch approach requires an over-simplification of the process. This type of approach, however, does allow the reader to view transportation policy decision-making in a comprehensible manner and to draw, at least, preliminary insights and conclusions as to policy making as an ongoing activity.

In general, the Executive Branch formulates and recommends transportation policy to the United States Congress. Once the specific details of the policy are established by Congress in the form of statutes and funding programs necessary for the implementation of the policy, the Executive Branch again comes on to the scene to carry out the policy within Congressional guidelines. Finally, the federal judiciary has the responsibility for determining whether the policy established by Congress and carried out by the Executive is followed when particular actions are taken. The judiciary provides a forum through which individual or groups of citizens can challenge the policy or its implementation.

A. The Executive Branch

Within the executive branch of government, no agency presently has jurisdiction or control over all aspects of transportation decision-making. Besides the various roles which the Department of Transportation plays in the administration and regulation of transportation and in transportation research, several other executive offices, including the Departments of the Treasury, Defense, Commerce, Health, Education, and Welfare, Agriculture, Interior, Housing and Urban Development, are actively engaged in these areas. Moreover, several independent regulatory agencies, such as the Interstate Commerce Commission, the Civil Aeronautics Board, the Federal Maritime Commission, and the National Aeronautics and Space Administration, also play a variety of intertwined roles in transportation decisions.

Ultimately, however, it is the office of the Presidency which has the final decisional authority within the Executive Branch. As head of this branch, the President has the final responsibility for the formulation of any proposed policy. By presenting his programs to Congress through his presidential messages and his budget, by exerting necessary influences upon Congress in an attempt to insure that his programs are put into law and, thus, into a national policy, he "sets the agenda for public decision making." [5] As two widely respected political scientists have put it, "few major undertakings ever get off the ground without presidential initiation; the president frames the issues, determines their context, and decides their timing." [5]

In an over-simplified, general sense, policy decision-making by the President occurs in a rational sequence of events: (1) data gathering and interpretation; (2) formulation of the goals and priorities of the policy; (3) examination and assessment of the various alternatives of the policy; (4) recommendation of the policy choices; (5) authorization of actions designed to accomplish the recommendations; (6) design and implementation of the policy; (7) application of the policy; and (8) continued reexamination and reassessment of the policy under actual working conditions. [6]

With little doubt, this scheme is, again, an over-simplification of the actual decision-making process. Perhaps the most realistic statement on policy making has been offered by Charles E. Lindbloom who describes the administrator's activity as "the science of muddling through." [7] The Chief Executive's role in national policy might be viewed as "muddling through" the above eight steps. With respect to transportation, DOT had been charged by Congress with the responsibility of formulating and recommending National Transportation Policy under the supervision of the President. [8] The DOT is essentially a combination of previous intermodal agencies. Fundamentally, DOT was created for

> . . . the development of national transportation policies and programs conducive to the provision of fast, safe, efficient, and convenient transportation at the lowest cost consistent therewith and with other national objectives, including the efficient utilization and conservation of the Nation's resources. [9]

Moreover, the Congressional Act called for the Department to assemble a coordinated and efficient administration for federal transportation programs and service, "to be provided by private enterprise to the maximum extent feasible;" to successfully effect "national transportation objectives" by encouraging cooperation among the Federal, the State, and the local governments and "other interested parties;" [9] to "foster the use of new technology" by actively seeking out aid from America's private industrial sector; and to assist in the development of future governmental transportation policies by requesting legislation appropriately "designed to achieve these policies." [10] Finally, a recent report of the U.S. House of Representatives declared that the ' primary objective" behind the establishment of DOT was "to better coordinate the fragmented and somewhat wasteful separate modes of transportation, and to guide and stimulate the growth of our transportation system . . . in the years ahead." [11]

In general, it is the duty of the Secretary and the Under Secretary of the Department to act as chief administrators in the "overall planning, direction, and control" of the Department. [12] Directly beneath them in the organization of DOT are (1) the Assistant Secretary for Policy and International Affairs, (2) the Assistant Secretary for Systems Development and Technology, (3) the Assistant Secretary for Environment and Urban Systems, (4) the Assistant Secretary for Safety and Consumer Affairs, and (5) the Assistant Secretary for Administration. Organized on a "cooperative functional basis rather than as advocates for particular modes" of transportation, the Assistant Secretaries represent "staff units" designed to encompass the total responsibilities of the Department. [13]

The differing modes of transportation are affiliated with one or more of the seven agencies of DOT. First, the Federal Aviation Administration (FAA), in general, is responsible for air traffic in America and all matters associated with the traffic it regulates. The Federal Highway Administration (FHWA) handles DOT's highway transportation programs. Third, the Federal Railroad Administration (FRA) has been delegated the duty of providing the federal government's "support of rail transportation activities." The Urban Mass Transportation Administration (UMTA) is charged with assisting in the development and planning of mass transportation hardware and software. Fifth, the National Highway

Traffic Safety Administration (NHTSA) possesses federal authority in programs to improve motor vehicle and pedestrian safety. Other functional agencies of DOT are the United States Coast Guard and the Saint Lawrence Seaway Corporation. [14]

Another organization of the Executive Branch of the federal government which has a significant impact upon transportation policy in the United States is the Corps of Engineers. With respect to the Corps, DOT has not been given jurisdiction over navigable waters. This responsibility remains with the Corps of Engineers. [14, p. 141] An independent regulatory commission, the Interstate Commerce Commission (ICC) was first established in 1887 as a political response to midwestern agrarian requests that the federal government step in to squelch unfairly high railroad rates for the transportation of farm products. [15] The ICC has the statute authority of regulating, "in the public interest," the activities of all carriers engaged in interstate commerce and surface transportation (railroads, truckers, busses, freight forwarders, water carriers, oil pipelines, transportation brokers, and express agencies). This includes both transportation economics and transportation service of these carriers. [12, p. 462] The Civil Aeronautics Board (CAB), also an independent agency, has a wide range of authority in the area of civil aviation, especially with respect to economic considerations such as tariffs, rates, and fares for passengers and freight. [12, p. 396] This authority concerns both national and international air transportation. The Civil Aeronautics Board, also, made $53,600,000 available to local areas which are not normally served by air transportation in 1972, and the 1973 estimate for the same purpose had jumped to $54,000,000. [11, p. 29] Another federal independent regulatory agency which deals with national transportation matters is the Federal Maritime Commission (FMC). Established to regulate "waterborne shipping in the foreign and domestic offshore commerce of the United States," the FMC handles (1) agreements between common carriers, (2) the maritime practices of common carriers, (3) tariffs, (4) licenses for shipping freight over the oceans, (5) passenger indemnity, (6) oil pollution, and (7) examines and pursues informal complaints. [12, pp. 426-428]

A recently established federal independent regulatory agency (December 2, 1970), the Environmental Protection Agency (EPA) attempts to harmonize and integrate the federal government's activities in environmental pollution controls. [12, p. 351] The National Aeronautics and Space Administration (NASA), on the other hand, handles research programs relating to "problems of flight within and outside the earth's atmosphere." NASA also develops, constructs, tests, and operates vehicles designed for air travel. [12, p. 406]

Finally, three additional Executive cabinet-level departments are directly engaged in activities which bear upon the Nation's system of transportation. First, the Department of the Interior has ultimate authority in the "management, conservation, and development of the natural resources" of the United States. In line with this authority, the Department works to coordinate federal and state recreational programs. [12. p. 465]

The Department of Housing and Urban Development (HUD), a cabinet-level Department, has the duty of assisting in "providing for sound development of the nation's communities and metropolitan areas." More specifically, HUD has primary responsibility within the Executive Department of accomplishing a maximum degree of coordination among the numerous federal projects and programs which impinge upon and threaten to have a major impact upon metropolitan, urban, and suburban development in America. [12, pp. 213-214]

A National Land Use Policy Act would also significantly increase the legal and administrative functions of the Department of the Interior not only with respect to land use but also in the area of transportation.

Second, the Department of the Agriculture coordinates many of the above federal projects as they relate to rural development in America. [12, p. 241] Third, the promotion of the Nation's economic development is channelled through the Department of Commerce. [12, p. 270]

From the above discussion, it is obvious that there is a fragmentation of transportation functions within the Executive Branch of the Federal Government. Even though the President does have a Department of Transportation, no one agency, office, or department—including DOT—within the Executive can control or has the responsibility to control, all transportation matters in America. A variety of both cabinet-level Departments and independent regulatory agencies have some say in activities concerning the movement of people and goods. If

a National Transportation Policy is ever to be established, this situation must be remedied. Otherwise, a common, unified effort in the formulation, recommendation, and implementation of that policy within the Executive will be virtually impossible.

Given this large degree of fragmentation with the Executive Department, there is a need to bring all of the above regulatory aspects into a single body of transportation regulatory activities. This agency should be concerned with all modes of transportation and be responsible for those activities currently carried out by the Interstate Commerce Commission, the Civil Aeronautics Board, and the Federal Maritime Commission.

There is also a great need to reorganize the Executive Branch. While President Nixon had suggested executive reorganization, his plan would eliminate the Department of Transportation, which, we feel, is an unnecessary plan at this time. Reorganization around transportation policy will be necessary at some future date. To forge ahead with reorganzation today or in the near future, however, involves a premature step. The first order of business should be the development and establishment of national land use and transportation policies by the Congress. Then and only then should reorganization be carried out. The organization should fit the policy, not vice versa.

B. The Legislative Branch

Fundamentally, it is the responsibility of the Congress of the United States to establish national policy by enacting legislation which legitimizes the policy and by funding specific programs which permits implementation of the policy by the Executive. In a word, it is the Congress through its legislative power that determines which of a variety of alternative programs will be executed by the national government. [16]

In the area of transportation, as with other specific policies, while the President and the Department of Transportation do have significantly important roles in the development and recommendation of transportation policy, when all is said and done it is Congress that is the key actor in establishing "National Transportation Policies." It is Congress that passes the laws which establish requirements and standards and determine the appropriations that are (or could be) the National Transportation Policy.

The Congressional framework for dealing with national policy is, perhaps, even more fragmented than that within the Executive. As of the writing of this report, at least seven of the standing committees of the House of Representatives and seven of the standing committees of the Senate were considering important transportation bills. [17] A list of these committees is contained in Table 1.

Beyond a doubt, there is a considerable degree of overlapping with respect to committee jurisdiction in the transportation area. Many bills are submitted to more than one committee.

This committee jurisdictional problem is well illustrated by a recent (March 23, 1971) bill introduced to the Senate by Senator Charles Percy of Illinois. Senator Percy's bill, which he titled "The National Transportation Development and Financing Act of 1971"

TABLE 3.1
STANDING COMMITTEES IN THE UNITED STATES CONGRESS CONSIDERING TRANSPORTATION BILLS IN 1972

Senate Standing Committees	House Standing Committees
Appropriations	Appropriations
Banking, Housing & Urban Affairs	Banking and Currency
Commerce	Interstate and Foreign Commerce
Finance	Ways & Means
Government Operations	Government Operations
Interior & Insular Affairs	Interior & Insular Affairs
Public Works	Public Works

(S.1344) was referred to the Senate Committees on Banking, Housing and Urban Affairs, Commerce, and Public Works since all of these had some degree of jurisdiction in the area covered by the transportation bill.

An important bill which would have great impact upon transportation planning is the Land Use Policy and Planning Assistant Act of 1972 (Jackson, S.632). Submitted to the Senate by Senator Henry Jackson of Washington, the bill has run into committee jurisdiction difficulties because it contains a specific proposal designed to withhold highway funds as a sanction against states for failure to comply with land use planning requirements.

Currently both the Senate Public Works Committee and the Senate Interior and Insular Offices Committee are involved in a jurisdictional controversy over the Jackson Land Use Bill as the former Committee is concerned about the proposal to withhold highway funds and the lack of a function for the Environmental Protection Agency in the bill. [18]

These jurisdictional conflicts are supporting evidence of the lack of coordination within the Legislative Branch. If a National Transportation and Land Use Policy is ever to become a reality greater legislative coordination is necessary. We, therefore, suggest and **strongly** recommend that a joint House-Senate committee be established to formulate policy and coordinate all transportation matters.

The sources and instruments of conflict between the two federal branches are great in number. [19] Besides a great variety of institutional differences between the two branches, there are also differences with respect to constituencies, term of office, [20] interest group receptibility, and policy outlooks.

At any rate, however, if a National Transportation Policy is to become a reality in the United States, cooperation, rather than conflict, must prevail between the Executive and Legislative Branches. This is not to say that major policy alternatives and value differences should not be openly discussed, assessed, and considered by the various actors. Such would strike at the heart of democratic decision-making. It is to say, however, that common goals should be identified and a cooperative effort be undertaken in reaching these goals for a National Transportation Policy.

C. The Judicial Branch

In general, the Judicial Branch of the Federal Government determines whether the policies established by Congress are within the legitimate constitutional framework of the United States. Moreover, the judiciary examines particular cases of the implementation and execution of congressional policy and determines whether the particular actions or inactions of persons carrying out the policy are in line with the intentions of Congress. It thus provides a forum for individual and/or groups of citizens who wish to challenge specific national policy.

Specifically in the area of transportation, the judiciary has seen increasing involvement due to growing opposition by the public to continued urban highway expansion. This combination of litigation and public opposition has increased to such an extent that in many areas of the United States "major highway construction is now being contested." [21]

The State Level

In the past, state governmental administrative structure to deal with transportation problems has been mode-oriented. The effects of this traditional organization have been a concentration of expertise in the State Highway Departments and a resulting over-emphasis of highway construction programs to satisfy transportation demands. However, an increasing awareness of the interjurisdictional nature of transportation problems and an appreciation of the lack of coordination among the various modes at transportation interfaces have indicated the necessity of revised approaches to provide solutions. For instance, the decision to build an airport in a particular location may not only have important environmental consequences for a substantial area by increasing noise levels and airplane emissions, but will also create new communication and transportation patterns with the accompanying ramifications on the use of roads and population distribution. The trend of state response to the transportation problem has been reorganization into multi-modal agencies such as State Departments of Transportation. The following delineates two specific examples of the alternative state organizational approaches.

Virginia—A State Without a Unified Approach

Virginia governmental organization to deal with transportation continues to be mode-oriented and generally reflects a lack of balance among transportation modes, resulting in a dominance of policy and expertise by the State Department of Highways.

A. Aviation [22]

The State Corporation Commission (SCC) promulgates rules and regulations relating to airports and the operation of aircraft. The Division of Aeronautics of the Department of Commerce functions as the agency for administration of the laws of the Commonwealth with regard to (1) the licensing of airports and landing fields; (2) the construction, maintenance, and improvement of public airports; and (3) the promotion of aviation.

Airport project applications of municipalities or counties must be approved by SCC. Additionally, a municipality or a county must obtain the permission of the SCC to operate an airport. A municipality or county is required to designate the SCC as its agent to receive funds granted by the United States under a Federal Airport Act.

An Advisory Committee on Aviation which consists of seven members has been created within the State Department of Corporations to consult and advise with the SCC. There also exists as a political subdivision of the State a Virginia Airports Authority. The representation consists of five members appointed by the Governor, one member of the SCC, and there may be additional members representing political entities with review only as to the particular airport acquired which was previously controlled by that entity. The Virginia Airports Authority may acquire or construct airports and also functions to plan, establish, develop, construct, maintain, operate, and regulate airports and air navigation facilities within the State.

B. Highways

The State Highway Commission, composed of nine members appointed by the Governor, has authority concerning highways in Virginia. [22, §33.1] The duties of the State Highway Commission include: (1) selection of the location of routes, (2) to let all contracts for the construction of state highways, (3) to make traffic regulations, (4) to comply fully with federal acts, (5) to gather and tabulate information and statistics relating to highways, and (6) to review and approve policies of the Department of Highways and State highway objectives.

C. Public Service Companies

The regulation of Public Service Companies, including Transport Companies, is within the jurisdiction of the State Corporation Commission. [22, §56] The SCC is authorized to regulate rates and charges of Transport Companies. It is the function of the SCC to supervise, regulate, and control all air carriers. The SCC also regulates Motor Vehicle Carriers operating any motor vehicle for the transportation of passengers or property for compensation. In addition, railroad rates are regulated by the SCC.

D. Secretary of Transportation and Public Safety

The creation in the Governor's Office of a Secretary of Transportation and Public Safety represents an attempt at the state level to coordinate a particular program. [22, §2.1-51.7] The Office of the Secretary of Transportation and Public Safety is responsible for the following agencies.

(1) Department of Highways

(2) Virginia State Ports Authority—which functions to develop and improve the harbors or seaports of the State of Virginia without affecting the powers of the SCC. [22, §62.1]

(3) Virginia Airports Authority

(4) Division of Motor Vehicles—which controls the administration of motor vehicle license, registration, and title laws. [22, §46.1]

(5) Department of State Police

(6) State Highway Safety Division—which is charged with the responsibility of carrying out the State's highway safety programs. [22, §2.1-64.15]

(7) Office of Civil Defense

(8) Department of Military Affairs

E. The Transportation District Act of 1964 [22, §15.1-1342]

The Transportation District Act of 1964 represents state enabling legislation for the creation of a regional organization to carry on "comprehensive, continuous, and coordinated transportation planning" in accordance with Section 134 requirements. The declaration of policy recognizes that the development

of transportation systems, composed of transit facilities, public highways, and other modes of transport requires planning and action on a regional basis," conducted co-operatively and on a continuing basis, between representatives of the affected political subdivisions and the **State Highway Commissioner**" (emphasis added). In urban areas of Virginia contiguous to other states forming a single metropolitan area, solutions are to be jointly sought with the political subdivisions and highway departments of such other states. It is significant that the Virginia legislature expects the State Highway Commission to develop a comprehensive and balanced **multimodal** transportation plan. Any two or more counties or cities may constitute a transportation district, created by ordinance passed by the governing body of each participating county and city. The planning process provisions require that the transportation district commission shall cooperate with the governing bodies of the participating counties and cities, with the State Highway Commission, and with an agency of which the members of the transportation district commission are also members to provide the necessary interrelationship between the transportation policies and plans for growth and development. The function of a transportation district commission acting within a metropolitan area which includes states contiguous to Virginia is not to prepare a transportation plan nor to construct or operate transit facilities, but to cooperate with a metropolitan agency in the preparation of a transportation plan for the metropolitan area. [22, §15.. 1357(b)(1)] It was under the authority of this chapter that the Northern Virginia Transportation District, which functions within the Washington Metropolitan Area Transit Authority was created.

New York—A State With a Multimodal Organization

[23]

The New York "Transportation Law," effective September 1, 1967, created a State Department of Transportation (DOT) with multimodal transportation responsibilities. In addition, the responsibilities of the Metropolitan Commuter Transportation Authority in the New York area were extended to include rapid transit, surface transit, and bridge and rail commuter traffic. A new Niagara Frontier Transportation Authority was established to coordinate mass transportation and aviation efforts along the entire Niagara Frontier.

Prior to the 1967 Transportation Law, there existed several independent state agencies with authority as to the different transportation modes. The location of airports was determined by a resolution to construct an airport passed by either a board of trustees of a village, a local legislative board of a city, or a board of supervisors of a county. The project application must then have been approved by the State Commissioner of Commerce. The State Department of Public Works administered the construction of highways. The Consolidated Rapid Transit Law of 1941 provided that there was to be a Board of Transportation in a city with greater than one million inhabitants, empowered to operate any railroad acquired, owned, constructed, or provided by each city. The railroads were under the jurisdiction of the Transit Commission. The State Public Service Commission exercised the authority to regulate the rates of motor carriers and railroads.

However, the passage of the 1967 Transportation Law effectuated a transfer of the functions of the separate state agencies to the newly created State DOT. The activities of the Commissioner of Commerce relating to aviation, air commerce, airports, and other air facilities were transferred to the New York DOT. The responsibilities of the Department of Public Works were placed under the authority of the New York DOT. [24] The Office of Transportation in the Executive Department was transferred to the State DOT. The State Traffic Commission in the Department of Motor Vehicles was also transferred to the DOT. In 1970, major amendments to the Transportation Law were promulgated to unify all transportation activities within the single agency and thus the responsibilities of the Public Service Commission regarding the regulation of transportation were transferred to the DOT.

The general functions, powers, and duties of the New York DOT are delineated in Section 14 of the Transportation Law. The department is charged with the development of comprehensive, balanced transportation policy and planning for the state and "to coordinate and assist in the balanced development and operation of such transportation facilities and services in the state, including highway, mass transit, marine and aviation facilities." The department is to coordinate the development of a system of air routes and airports within the state. The DOT is to exercise all functions, powers and duties relating to traffic regulation and control. The jurisdic-

tion of the department extends to the preparation of plans, specifications, designs, and estimates relating to the construction of highways, canals, waterways of the state, and bridges. The Commissioner of Transportation is empowered to exercise the functions and duties of the commission of highways and the interstate bridge commission. A specific duty of the Commissioner of Transportation is to cooperate and consult with the Commissioner of Agriculture and Markets, the Commissioner of Conservation and Health, and the Board of Trustees of the State Historic Trust to provide for review of proposed transportation projects. Additionally, the commissioner shall coordinate the intercity rail passenger activities of the state.

With regard to the planning function, the DOT is authorized to formulate a comprehensive statewide master plan for transportation to provide for balanced development and coordination of efficient commuter and general transportation facilities. The commissioner is required to act as the state planning agency for metropolitan or regional urban transportation planning and for interstate comprehensive urban transportation planning. [24, §30] Plans for proposed municipal projects are to be reviewed by the DOT with regard to such projects being consistent with the statewide comprehensive master plan for transportation approved by the governor. [24, §50]

Article Five of the Transportation Law deals with the powers of the commissioner in respect to common carriers. The rates and service of railroads and rapid transit are to be fixed by the commissioner. Article Six concerns bus lines and bus companies. The commissioner is charged with the general supervision of all bus companies. [24, §142] An important limitation to be noted, however, is that the commissioner has no jurisdiction over rates of fare, route designations or certification of public convenience and necessity, or service regarding any bus line operations within a city having a population greater than one million.

Conclusion.

The reorganization of state administrative structure into multimodal transportation agencies is a necessary preliminary step in order to provide coordinated, long-range solutions to transportation problems. In the context of a future national policy recognizing the need for the integration of transportation and regional land use development, it is recommended that the federal government provide tangible incentives to encourage state consolidation of transportation functions.

The Local Level

American federalism should not be viewed as a two-layer governmental device between Washington, D.C., and the fifty state capitals. The political, legal, constitutional, and fiscal relationships between the states and the nation are too intricate, too complex, and too involved for any such conceptual approach. [6, p. 125] A more realistic and more practical view of American federalism has been offered by Morton Grodzins in his "marble cake theory." Fundamentally, Grodzins argues that an

> Accurate image is the rainbow or marble cake, characterized by an inseparable mingling of differently colored ingredients, the colors appearing in vertical and diagonal strands and unexpected whirls. As colors are mixed in the marble cake so functions are mixed in the American federal system. [25]

Thus, the "new federalism" which has evolved from the Constitutional prescriptions of 1789, is essentially a cooperative effort between the national government and the state government and the state governments in most federal-state relationships. Rather than mandatory acceptance of federal projects and programs by state governments, the normal federal-state relationship is one of "voluntary compliance." [26] It is true, then, that the federal structure of government of the United States has altered drastically especially during the twentieth century. But while this "new federalism" was developing, another significant event was occurring—the American city was becoming a reality.

Cities have no rights, no federal status under the Constitution. The federal relationship is national-state, it does not include the local level in federal decision-making. With greater than 70 percent of the nation's population residing in urban areas in 1970, for federal programs to reach the greatest number of people in America, they must filter through the lower levels of decision-making—the cities.

But the federal-city relationship is plagued by a "constitutional and political paradox." [6, p.148] An American city is

subordinate consititutionally, legally, and politically to the state in which it is located. It is a creation of the state government and, therefore, a creature of it.

Much has been written about the "new federalism"--a forging of the federal government and the local government to create a novel and unique national-local approach to the nation's problems. While the constitutional, legal, and political difficulties between the cities and their states will continue to exist for some time in the future, local governments can, at least, move to begin to develop this relationship through various attempts and programs designed to build more rational, more operational, and stronger units of local government. We now turn to a discussion of a variety of these prospects for the future.

Some Moderate Approaches

Leonard E. Goodall in his book *The American Metropolis* offers an extensively comprehensive list of approaches for more rationally governing America's metropolitan areas. Borrowing from Goodall's organizational scheme, we shall first analyze what he calls "moderate approaches" and secondly his "far-reaching approaches" to metropolitan governance.

1. **Annexation.** By far, the most popular and widely used method is annexation. Normally requiring a popular referendum in the annexing city and/or the region to be annexed, [27], annexation is most frequently justified as a method to broaden the city's tax base and to provide additional needed city services to the new area under consideration. While it does greatly simplify the governing process because it requires no new political structures or alterations in current political structures, annexation is an unrealistic approach for the nation's largest metropolitan tracts which have enough problems already facing them. [28]
2. **Extraterritorial Powers.** Approximately thirty states have granted to their metropolitan areas the power to become actively involved in and, to a certain extent, regulate territories outside their city boundaries. While this approach does allow the city to provide services for areas outside its limits and to draw in additional needed revenues, it is surely weakened as most "state grants of power are...effective only if there are large, unincorporated areas adjacent to the municipality, a condition rarely existent in the larger metropolitan areas." [29 and 28, p. 84]
3. **Transfer of Functions.** By transferring certain functions to the state or county governments, many urban areas have attempted to avoid special difficulties in governance unique to that area. On paper, this approach appears neat and concise, but in actuality it is merely a way of avoiding these difficulties as county and state governments are usually ill equipped and unwilling to squarely face the urban mess of America.
4. **Voluntary Association.** A new mechanism used in many metropolitan areas is the voluntary association By banning together in an attempt to solve common problems, major metropolitan areas have found the voluntary association to be mutually beneficial to all participants involved. While the specific functions of these associations cover a wide spectrum, "one of their more important areas is the development of communications channels among governmental agencies." [30] The Advisory Commission on Intergovernmental Relations offers a list of some of the more common characteristics of these associations. Among them are (1) they are frequently interstate, cutting across state boundaries; (2) local elected officials and often representatives from the state governments are involved in whatever decision-making activities the associations have; (3) they are normally "forums for discussion research and recommendation only," rather than governmental operating institutions; (4) they are involved in a wide variety of common interests; and (5) they possess a staff of full-time employees. [28, p. 89]

Two examples of voluntary associations are the Northeastern Illinois-Northwestern Indiana Regional Transportation Planning Board and the Southeast Michigan Council of Governments. [31] While these associations do usually appeal to those involved in decision-making for metropolitan areas, they suffer because they have no real decision-

making and implementation power outside the voluntary agreement of the parties involved.

5. **Special Districts.** Perhaps the best example of the use of the special district to solve governmental problems is the school district. Special districts, however involve a variety of governmental activities other than education. Existing as relatively autonomous units of government to perform a specific public service, special districts have been organized across the United States to handle "recreation, sewage disposal, airports, planning parking, and mosquito abatement" as examples, and they normally have their own separate taxing and bonding authorities. [32] While the idea appears as a highly desirable approach to the solution of specific urban problems, special districts do not allow for the coordination necessary for a comprehensive view of our metropolitan difficulties, [33] and they can easily lead to patronage for special interest groups in the district's realm of issue area.

6. **Contractural Arrangements.** Since one of the greatest problems facing units of government at the local level is the lack of coordination of facilities and services, several devices for inter-governmental cooperation have been devised. These arrangements can and do vary from straightforward information exchanges between governing authorities to the creation of novel units of government. [28 p. 93] The best known type of contractural arrangement, however, is the Lakewood Plan, by which a municipality purchases any or all of its services from the county government. The legal autonomy of the municipality is upheld under the Plan, and interrelated services and functions can be coordinated at the county level. At the same time, though, the Lakewood Plan in particular and contractural arrangements in general have led to a maze of small communities almost completely dependent upon the county for their functional lives. They are simply too small to "accept all of the responsibilities of providing municipal services. [34]

Far-Reaching Approaches

Four major "far-reaching approaches" have been proposed as solutions to governing metropolitan America more effectively, according to Goodall. [28, p. 95] While these four approaches are by far the most comprehensive proposals submitted to date, they are likewise extremely controversial and subject to intense public debate and political resistance.

1. **Consolidation of Similar Governmental Units.** Used primarily to streamline the proliferation of school districts, programs to consolidate similar units of government have, in the past, created a great amount of controversy among residents in the areas affected. Usually, the controversy was centered around a belief by a large number of the population that consolidation of similar units would strip the local area of its governing authority and dilute its autonomy. A case in point occurred in the mid-1950's in Illinois. A move to consolidate the cities of Champaign and Urbana, Illinois, by the Urbana Civic Committee—a group composed fundamentally of faculty members of the University of Illinois—was soundly defeated by opposing groups in both communities. [35 and 28, pp. 98-100] Basil G. Zimmer and Amos H. Hawby, moreover, have argued that opposition to such schemes of metropolitan reorganization is higher among both officials and the public in the suburbs than in the central city and "declines by size of metropolitan area." [36] A few of these consolidation attempts have been successful in the past, however, especially in the smaller metropolitan areas. A move to consolidate Newport News and Warwick, Virginia, was completed in 1958. In 1961, Winchester and Winsted, Connecticut, consolidated, and Sacramento and North Sacramento, California, combined to form one unified city in 1965. [28, pp. 100-101]

2. **City-County Consolidation.** The basic philosophical argument behind the city-county consolidation approach to the nation's metropolitan difficulties is that it will "eliminate conflict, overlapping and duplication, and lead to a government that is more efficient and,

because it is simpler, more easily accountable by the votes." [28, p. 100] While the city-county consolidation method is highly desirable, at least on paper, only four consolidation efforts in the past few years have been politically and legally successful: (1) Baton Rouge-East Baton Rouge Parish county, Louisiana; (2) Nashville-Daridson County, Tennessee; (3) Miami-Dade County, Florida; and (4) Jacksonville-Duval County, Florida. [37] Recent research on numerous city-consolidation election attempts indicates that familism, life style, and demographic distance of the voters have significant impacts upon city-county consolidation election outcomes. [38] Even when these types of elections are successful, however, there are still other problems for the city-county consolidation approach. Most serious, perhaps, is that consolidation is based upon the assumption that the county government is well suited to "administering urban functions." This, however, is not always true. [39]

3. **City-County Separation.** During the nineteenth century, there were several moves to separate metropolitan governments from their county governments. Today, however, the city-county separation scheme is unused except in Virginia where a city, having accumulated a population of 10,000 or greater, may separate from the county. Other than in Virginia, though, city-county separation is a "dead issue." [28, pp. 105-106]

4. **Metropolitan Federalism.** Finally, the concept of metropolitan federations has recently creeped into the various proposals designed to alleviate the problems of metropolitan America. [37, p. 48] Fundamentally, a federal structure of metropolitan government attempts to develop a "general government covering the entire area concerned and providing services of an area-wide nature and some type of subunit of government which has a more narrow geographic base and provides essentialiy local services." [28, p. 106] In simplier terms, a "metro" government is granted political, administrative, and legal control and authority over metropolitan-wide policy while the former local governments are kept intact to perform local functions. True, the metropolitan federalism approach offers a solution to many of the current administrative and fiscal difficulties facing the metropolitan American, but it also is likely to threaten the local "social, political, and psychological" systems of values. [39, p. 309]

Metropolitan Reorganization: A Concluding Comment

We have separately analyzed the various schemes which have been proposed as "solutions" to the metropolitan mess. It is quite obvious from this discussion that no single scheme, in and of itself, will wipe away all of our local problems—transportation included. Some sort of governmental organization equipped to make transportation decisions with legitimate **authority** for the integrated local area is required. To date, no such organization exists. For an effective system of transportation to exist in the nation's metropolitan areas, this must become a reality.

Transportation Systems Planning In Urban America: A Complex And Harassing Problem

There have been a few successful attempts to develop and implement integrated transportation policy at the local level of government. While these attempts have not been, quite honestly, highly successful, not because the organizations involved have not expended effort but due to a lack of necessary political and legal authority, we shall present a discussion of two of them—the Northeastern Illinois-Northwestern Indiana Regional Transportation Board and the Southeast Michigan Council of Governments—as examples of regional organizational efforts which are presently engaged in on-going activities. Our analysis of these two organizations will allow us to examine what efforts have been made in the past and to review the massive complexity of organizing for transportation planning at the local level.

The Northeastern Illinois-Northwestern Indiana Regional Transportation Board was established to administer the Urban Mass Transportation Administration of the Department of Transportation "planning grant study,

assuring the necessary coordination of inputs and outputs," to attempt to implement transportation plans and programs, to offer "policy guidance to the technical planning staff," and to guarantee that all interested parties—"transit operators, citizens, civic groups, and the various units and levels of government"—participate in the planning operations. [40]

Participation in the activities of the Board is composed of the following political and governmental organizations: (1) fifteen counties—seven in Wisconsin, six in Illinois, and two in Indiana; (2) seventeen cities with population in excess of 50,000 people—five in Wisconsin, ten in Illincis, and two in Indiana; and (3) an additional 1,200 separate political units in Illinois alone. Moreover, the transportation planning activities of the Board cover a grand total of 7,346 square miles in area. Of these 7,346 square miles, Illinois contributes the greatest with 3,719, Wisconsin the second most with 2,688, and Indiana the least with 939. Finally, approximately 8,365,000 people resided in the planning area covered by the Board in 1960. 6,221,000 were in Illinois, 1,570,000 were in Wisconsin, and 574,000 in Indiana.

While these statistics are undoubtedly impressive, there are severe difficulties with this, as with other planning organizations. First, the organization has no legal basis to raise revenue. Funding is on a totally voluntary basis by the participants. Also, the organization has no statutory authority. Its functions and authority are limited by law to an advisory capacity.

A second type of regional organizations which has been created are the Councils of Government (COG). Typically, a Council of Government is a vehicle for a continuing comprehensive planning effort which is geared to channel in funds from the federal government. The Southeastern Michigan Council of Governments (SEMCOG), for example, lists its basic activities as (1) surveillance and monitoring, (2) plan element completion and reappraisal, (3) procedure development, (4) regional services, (5) plan implementation, (6) data systems, (7) program administration, (8) special projects, and (9) special programs. [41]

Membership in COG organizations is open to all cities and villages, counties, school districts, and community colleges and townships within the area covered by the particular organization. [42]

As with the transportation planning boards, however, Councils of Government are voluntary associations. SEMCOG, for example, has a potential for 373 governmental unit members in the seven county area in which it operates. Only 106 of the 373 (29%) are participating members! This statistic alone indicates the most outstanding problem with COG organizations.

Again, COG organizations have only planning authority. They have no authority for implementation. As advisory organizations only, even the best laid programs they may design have no guarantee of even being put into action.

In line with the fragmentation of local governmental units discussed in the first part of this section and with the lack of implementation authority which present regional transportation planning associations are faced with, we feel that associations with authority to not only plan but to also implement their plans should be developed at the local levels throughout the United States.

Non-governmental Groups

In considering those non-governmental actors actively engaged in transportation decision-making either directly or indirectly we are primarily concerned with interest groups. Interest groups, according to David B Truman are groups "that, on the basis of one or more shared attitudes, make certain claims upon other groups in the society for the establishment, maintenance, or enhancement of forms of behavior that are implied by the shared attitudes." [43] They are, in a word, private, non-governmental associations which attempt to influence governmental decisions in one way or another.

In the area of transportation, a great number of interest groups are actively involved in attempts to encourage federal transportation policies in this direction. Within the Department of Transportation, for example, nine registered lobby groups have on-going communications with the Federal Highway Administration, four with the National Highway Traffic Safety Administration, eleven with the Federal Railroad Administration, four with the Urban Mass Transportation Administration, and forty-two with the United States Coast Guard! The general scope of these many groups varies all the way from the National Governors Conference to the Marine Cooks and Stewards, from the National League of Cities and the U.S. Conference of Mayors to

the Boy Scouts of America and the Motorboat and Yacht Advisory Panel.

The great diversity in both numbers and goals of interest groups in America is reflective of the large extent of heterogeneity of this Nation's people. As one author has put it, the United States "is composed of an endless variety of economic and social interests, class configurations, ethnic and religious groups, occupations, regional and subregional interests and loyalties, values and beliefs." [44] Interest group membership tends to vary directly, however, with income, occupation, education, residence, and other measures of social and economic status. [45] Several studies have indicated, for example, that most residents of urban areas belong, at the most, to no more than one organized group. Moreover, in most cities, the majority of the residents belong to no organized group at all. [46] And, finally, since the group's goals are determined by "the interactions within the group," and since the great majority, if not all, of vested interest groups are controlled by oligarchical decision-making structures, the group's leadership, its inner decision-making structures, is normally most influential in defining the objectives and viewpoints of the group. [47]

Interest groups in America employ a variety of techniques in their attempts to influence the content of governmental policies. Among these techniques are (1) attempts to manipulate public opinion, (2) the persuasion of legislations through lobbying, (3) communicating with and supplying information to administrative heads and agencies, (4) providing "expert" opinions in the selection of justices for the courts, (5) actively engaging in litigation, (6) inter-group lobbying, [47, pp. 130-142] (7) organizing public opinion in favor of the group's objectives, [48] (8) attempts to influence the outcome of elections for public office. [49] Through these various techniques, interest groups play significant roles in the determination of public policy for all three levels of government. If we assume that transportation and land use goals can in fact be formulated at national, state and local levels, any programs aimed at formulating and implementing the corresponding policies will have to anticipate the above tactics.

In dealing with interst groups in the policy formulation process, both the administrator and the politician must have some reliable method of assessing the relative strengths of the many groups which are likely to approach them. Daniel R. Grant and H.C. Nizon have provided a comprehensive list of the several variables which must be considered in determining a group's political muscle.

The relative strength of the following components may vary, but all play a part: (1) the size of the group's membership; (2) the extent of cohesion and inter-group unity among the membership; (3) the relative degree of geographic distribution among the group's members; (4) the social status and prestige the group has been assigned by society; (5) the organizational tightness and leadership effectiveness of the group; (6) the extent to which the group's program—its values, goals, and objectives—is consistent with the prevailing social norms, values, attitudes, and beliefs, and (7) the degree to which the current political environment is conducive to the group's functional operation. [27, pp. 215-217] In general, as any or all of these seven variables increase, the strength of the group and, thus, its probable level of effectiveness also increases.

Interest groups are "alive and well" at the Federal level. In regulatory matters, they often find the regulatory agencies among the most faithful advocates for the companies they represent. Similarly, interest groups develop **advocates** among the halls of Congress. Members of Congress are aware of the logrolling leverage inherent in the power to designate which districts will be favored with bridges, canals, and the like. When DOT was created back in 1966, they jealously guarded their budgetary right to make the specific, line-item "expenditures which often justify the term "pork barrel." The version of DOT which emerged from Congress did not have the power to establish criteria for transportation investments. The maritime industry was left untouched due to lobbying efforts of the labor, shipbuilding and shipowner interest groups. Instead of reorganizing our chaotic regulatory systems, the DOT legal staff was with little more than the right to respond to cases before the commissions.

Several interest groups were at at work to stop DOT from making evaluations of transportation investment. The highway lobby, constituted with such organization's as the AASHO (American Association of State Highway Officials), worked for the Bureau of Public Roads retaining final authority over committing federal highway funds. The stakes in the investment criteria fight were quite high for these few companies since the criteria

then used was flagrantly "pork barrel." The Corps of Engineers used criteria which "justified" any project which made it cheaper to move cargo by barge than by truck or rail over the same distance. Since the barges pay few taxes and since the fixed costs of building and dredging were to be largely ignored, the formula invariably favored the project. To make sure that DOT did not meddle Congress included the formula to be used and specifically forbid comparative evaluation of canals with other modes.

DOT was also forbidden to compare the relative costs and benefits of investments underwritten by **any** "grants-in-aid programs authorized by law." This constraint included expenditures on highways, airports, urban transit systems, and some railroad expenditures. Moreover, the secretary is subject to section 1653 which happens to read:

Nothing in this chapter shall be construed to authorize, without appropriate action by Congress the adoption, revision, or implementation of—

(A) any transportation policy, or

(B) any investment standards or criteria.

Thus although a rational unified investment criteria was clearly advocated, Congress retained the authority to pass on any criteria which might be suggested. Given the current "family" arrangements among industry interest groups and Congress, the future of such criteria is still in doubt.

The operating political environment is especially relevant when considering interest group activity in the fifty states. Since many of the Nation's transportation programs are the products of the state governments, it is necessary that we turn to a brief examination of interest groups at the second level.

In general, the "political and social structure of the state" is the major determinant of the scope, nature and breadth of interest group activity. [50] More specifically, while the wealthy, urban, and industrial states display a greater proliferation of interest groups, the very number of these groups tends to diminish the probability that any single group or coalition of groups will dominate governmental decision-making. Poor, rural, and agricultural states, on the other hand, claim fewer groups. However, the likelihood of interest group control of the state's policies is greater. [39, p. 88] Finally, interest groups representing business type activities are the "most frequent participants in the influence process in state politics." [51]

Hence, the number, type, and strength of potential non-governmental actions in transportation policies at the state level of government varies from state to state. In a state like California, we find a large number of interest groups with countervailing powers attempting to insert particular objectives in the policy-making process and in Montana, alternatively, we find fewer but each has a greater say in the policy decision.

At the local level of government, interest groups tend to be especially influenced in getting their ways. Because the groups are usually located in the community and have social, economic, and political ties which are well entrenched in the local area, the chances of their affecting local policies are greatly enhanced. [52]

A number of various types of local level interest groups have been identified by Thomas R. Dye. Among them are (1) civic associations which normally plead for "the welfare of the community," (2) business groups which are greatly diversified according to their particular interests but are also prone to be the "most influential of all group interests in community politics," (3) newspapers which can greatly control the editorial slant and content of community information, (4) labor unions which are most active at the state and national levels but still argue for "bread and butter" programs in localities, and (5) religious organizations including churches which fulfill their participatory share in local decision making. [39, pp. 248-255]

Finally, **socio-economic groups** of citizens within the community are distinguishable according to the type and quality of governmental services they expect and desire. Higher income groups normally show a high degree of support for governmental actions which led to a stimulated economic growth for the community and are planned to provide both the "comforts and necessities of life." Lower income citizens, on the other hand, are much more concerned with governmental policies designed to offer the private, rather than the public, "allocation of goods through the maintenance of only traditional services and, consequently, a low tax rate." Professional city managers are more closely aligned with the higher income group, as they also desire economic growth and an abundance of amenities for their communities. [53]

Several studies of decision-making at the local level give support to our observation that interest groups are well aware of the effects of transportation policy on property values. A 1971 study in the Little Rock and North Little Rock area by Richard W. Griffin of Georgia Tech found transportation decisions to be a key issue in the formation of alliances. The conclusions of the study, which interviewed economic, political, religious, and educational leaders, were as follows:

1. Local leaders, as a whole, are particularly concerned with on-going local transportation projects. This holds regardless of the mode of transport considered and regardless of the method of moving people be it by land, sea, or air.
2. Businessmen, elected politicians, members of the mass media, and labor leaders are especially interested with the transportation problems and issues of their communities. Ministers, educators, and civic and service association heads are not as interested as the former leadership types.
3. On very important transportation issues, the active leadership structure is normally composed of a coalition of high ranking federal politicians, particularly members of the United States Senate and House of Representatives, influential state officials and agencies, particularly the Office of the Governor and the State Highway or Transportation Department, and associated groups of interested and powerful local businessmen, particularly the local Chamber of Commerce.
4. On less important transportation issues, the active leadership structure is normally composed of relevant administrative agencies (such as the local Housing Authority or Airport Commission, and their directors), local political office holders (including the mayor, city councilmen and commissioners, and the like) and again, an association of powerful, local business interests (particularly the Chamber of Commerce).
5. The initiation of important transportation projects comes from upper levels of political responsibility and authority. The initiation of the less significant projects, on the other hand, is more likely to initiate at the local level among various political, administrative, and business type interests.

Our analysis of the non-governmental actors in transportation issues and policies is, to a great extent, incomplete. Because of the variety of methods through which vested interest groups and private individuals can insert their influence into the decision-making process, and because of the huge number of groups in the United States which actively seek to influence governmental policy, we cannot attempt a comprehensive examination of non-governmental actors in transportation policy in this report.

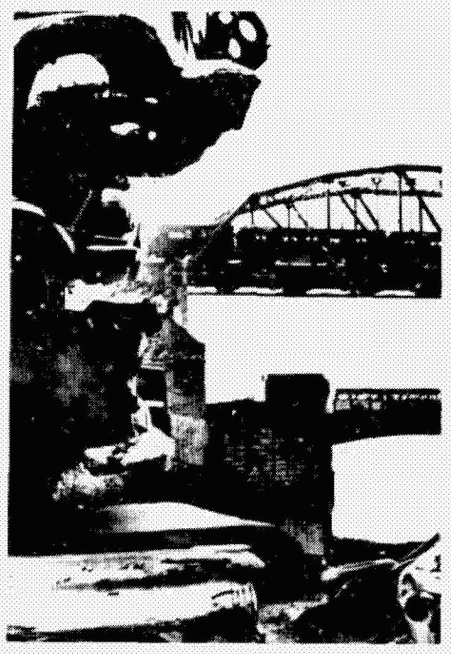
Our brief review of interest groups and their behavior at various levels of decision-making has demonstrated that there is more to rational land use and transportation planning than simply constructing an ideal model in which preordained social goals are implemented by some beneficent master designer. On the contrary, attempts to change the course of land use and transportation (which we agree should be changed to better reflect human needs) must effectively restructure the parameters and incentives which determine the behavior of the relevant interest groups.

Social and Economic Aspects Of Mobility

The location a given firm or family chooses for business or residence is obviously based on rational criteria; but the long run pattern of land use is a **large historical accident.** Most cities do in fact have long range development plans complete with zoning ordinances. But these plans are usually quite naive with respect to the types of life styles they impose on humans. Moreover, zoning laws and land use plans (such as they are) often prove very fragile. The plans do not carry the force of law, and the zoning laws are vulnerable to the property owners and developers who populate city councils.

Ideally, citizens would conceive of the long-run shape they desired for their community to include the life-styles they wished to lead. This long run view would dictate the size and composition of the various residence, recreation, school and business clusters which would evolve.

Inherent in this land use plan would be the appropriate transportation modes and



Ladybird, where are you when we really need you?

The Macadamization of a Landscape.

routes. Since tastes and technology change through time, flexibility would be an important element in the plan. And since it would be impractical to formulate and implement a **detailed** land use and transportation plan with the location of every activity preordained, citizen choice participation should establish a set of **priorities or rules** to be followed in the day to day decisions affecting mobility and land use. In the real world, land use remains subject to historical accident, and the transportation decisions made in one period provide important parameters and incentives for subsequent development.

In studies of urban development, many investigators have observed that activity location within cities is much more flexible than we usually suppose. Flexibility is of course a desirable attribute. However, the combination of relatively fixed transportation routes and facilities, a lack of land use planning, and shifting activity locations often leads to somewhat haphazard development.

Following Adam Smith, economists have tended to begin analysis of economic phenomenan by employing a model of free market decision making. It would, no doubt, be a useful exercise to outline the conditions and functional relationships **necessary** for such economic development to lead to optimal location of economic activities. But such an exercise is not required for us to observe that in the "real world" several of these conditions are missing. The free market system does not provide for the pricing of several important benefits and costs inherent in activity location.

The zoning laws attest to the fact that a negative externality is created, say, when a meat-packing plant is located in a residential area. Free markets simply cannot handle this type of allocation problem.

Another problem is that our metropolitan areas are broken into a myriad of governmental bodies all with their own tax rates and zoning laws which further disrupt locational decisions. Yet another part of the problem is that transportation rights of way tend to become fixed over time, since at any given point in time, the capital investment located along the way inhibits changing its route. Thus, Roman roads and American Indian trails have dictated many of the traffic patterns in European and American metropolitan communities.

All of this leads to a curious observation. Ordinarily we would think of the "transportation problem" as the best way to get from one **fixed** activity location to another. As it turns out, the locations of our activities change rather rapidly, and the transportation

problem involves trying to accommodate relatively fixed routes to the needs of population and activities which are changing their locations in a seemingly willy-nilly fashion.

Several factors have encouraged individuals and firms to shift their activity locations in ways antithetic to optimal land use. Most urban areas are Balkanzied into a multitude of semi-independent governmental units each having a certain amount of **veto power** over the community's land use and transportation decisions. Moreover, each area features changing property values, different taxing policies, and different governmental services. These factors, coupled with continual locational shifting among activities, tend to aggravate the mismatch between transportation needs and facilities. A broad trend of this type has been the move of businesses and upper income groups out from the central city to the suburbs. Urban blight has accentuated the move to suburbia. Once a neighborhood starts deteriorating, the best strategy for the individual property owner is to sell and move out. It is poor strategy to refurbish one's property unless every other property owner does the same. Thus a "prisoner's dilemma" accentuates the spread of urban blight; that is, as each property owner attempts to maximize his own position, his actions are duplicated by his neighbors and the whole community is worse off.

As the dislocation process has speeded up and as the city has expanded outward, the land values in the core central city have simultaneously decreased. A "zone of deterioration encircling the central business section" moves in to surround the downtown area with "regions of poverty, degradation, and disease, and their underworlds of crime and vice." [54] The pattern of urban blight is set, and its continued growth is difficult to control. For the most part the government's urban development and transportation policies have failed to account for the dynamics of this process. Only by dispersing the disadvantaged group geographically, socially, economically, and politically can these conditions be expected to halt. At the same time, effective programs to upgrade the disadvantaged are a necessary component of an over-all socially beneficial plan of action.

A transportation system which merely moves people from the middle-class suburbs to the downtown area contributes to the "blighting of the area it traverses." [55] Given the present distribution of economic and political power within urban areas, rebuilding and renovation of the blighted areas will be very unlikely to occur. [55] Middle class voters, who can escape the despicable conditions of their cities' blighted areas between 5 p.m. and 8 a.m. Monday through Friday and on the week-ends will not support tax and spending policies to redress these imbalances. Instead transportation expenditures will continue to aggravate rather than alleviate the process.

The incentives the federal government has given since World War II to new housing have also been a factor in increasing the shift

TABLE 3.2
POPULATION SHIFTS IN THE UNITED STATES — 1960 TO 1970
(Population in Millions)

Area	1960	1970	Change	
			Number	Percent
United States	178.7	202.5	23.8	13.4
Metropolitan Areas	112.4	131.5	19.1	17.0
Inside Central Cities	57.8	58.6	0.8	1.5
Outside Central Cities	54.6	72.9	18.3	33.5
Nonmetropolitan Areas	66.3	71.0	4.7	7.1

Source: U.S. Department of Commerce, Bureau of the Census, *Social and Economic Characteristics of the Population in Metropolitan and Nonmetropolitan Areas: 1970 and 1960.* (Current Population Reports, Series P 23, No. 37, June 24, 1971.)

to the suburbs. The low interest rates have encouraged new construction at the expense of refurbishing existing buildings. The basic population shift is shown by Table 3.2. In the past decade, our population grew from 179 to 203 million. There was a marked shift from central city residences to metropolitan areas outside the central city. While the central city population grew by less than one million, the suburbs grew by more than 18 million (34%).

Some Special Economic Characteristics of Transportation

We Americans have a proclivity for reaping the benefits of competition in free markets. This desire is thwarted in transportation markets by several economic features which preclude normal competition. The most obvious characteristic is the high fixed costs inherent in every transportation mode. These come in the forms of investment in rights-of-way, rail tracks, highways, bridges, tunnels, canals, and terminals, or in the vehicles themselves from bicycles to 747's. The proportion of fixed to variable costs differs considerably from mode to mode.

In addition, the fixity and transferability vary. A waterway is fixed and can only cater to ships and boats. Similarly, rail tracks can only accommodate trains. However, the rights of way for buses, trucks, and automobiles are generally the same. Capital intensity also differs among the modes. More important some types of transportation investment have "public" characteristics and are subsidized or actually performed by the public sector while other investment is purely private. Given the difficulty of deriving the appropriate "interest rate" and insuring that the appropriate amounts are invested, one would think that government would devote considerable effort to defining investment criteria and dispensing funds according to that criteria. But our budgetary systems do not allow for such comparisons.

These investment characteristics mean that there are differences in the economies of scale which may be realized according to the mode in question. Thus different types of public intervention are required, and different investment policies should be used for each mode. If we are to allocate resources effectively in this hodgepodge of private and public participation, it is necessary to develop investment criteria which account for the differences in fixed-to-variable-cost proportions.

Another characteristic is that the transportation **service** is largely "non-transferable" and "non-storable." That is, the services available at one time and place cannot be "stored" for use at another time and place. This characteristic, added to the fixed-cost feature, severely constrains the system's flexibility in responding to changing transportation needs.

Because of large fixed costs, limited transferability, and peak demands, the marginal costs of use during non-peak hours is often quite low. Economists traditionally advocate the use of differential pricing to reflect the low costs of additional subway passengers in non-peak hours and the high costs of additional passengers in rush hours. While the mechanics of differential pricing prove difficult in some cases, in others they prove an effective means of encouraging users to readjust their use pattern.

Transportation Externalities

Economists say an **externality** exists when one person's utility may be affected by an activity controlled by another. Needless to say, transportation activities abound with externalities. If one traveller decides to use a certain parking place, it is not available to the driver behind him. If one bus passenger smokes, it affects the physical comfort of the other passengers.

Externalities may be positive or negative. The fact that one's neighbors choose to take a bus makes it economical for the bus company to run a route through a certain neighborhood. Thus each individual benefits by the choice of others to ride the bus. The **numbers** of decision-makers and affected parties are important. Traffic congestion and air pollution become problems when too many travelers use a certain route. In the esoteric models of perfect competition individuals and groups are free to make trades which reconcile any externalities they may create for one another. But in real world situations the mechanism for these trade-offs simply does not exist.

Of the externalities generated by urban transportation the four most important are congestion, air pollution, accidents, and noise. Congestion is a direct function of the numbers of users for a given period of time. There are thresholds to the numbers of users a particular route or mode can accommodate. Some of the costs of congestion are easily calculated: estimates of the time lost by users can be multiplied by say, their wage rates. But

congestion also increases frustration, air pollution, accidents, and noise as the time of each trip is lengthened. As we have elaborated at other parts in this report, the public transit modes, rail, buses, and subway create much less air pollution, accidents, and noise per passenger mile than do automobiles—especially automobiles traveling at slow speeds.

Automobile Versus Public Transit

One basic urban transportation problem is that we have commuters traveling from **many** widely dispersed origins to a **few** urban central city destinations. The natural result is congestion. Most designs for "solving" this problem feature modal interface in which vehicles designed to gather passengers at many origins (such as the automobile) transfer them to another vehicle which is more efficient at moving people from a few origins to a few destinations (such as a rapid transit train). But while some designers have spent their time advocating systems featuring public transit, the others have been busily at work designing more and more freeways and multi-story housing for automobiles.

The increasing dependence on the automobile is shown clearly in Table 3.3. The percent of families owning automobiles has continued to increase and now is 80%. At the same time, the number of families owning more than one car has increased to nearly 30% These figures demonstrate a fundamental change in the life-style of suburbia. The multi-car family has transportation for the work trip as well as for household and school trips. The increased use of private automobiles for the trip to work has been a major factor in curtailing the demand for public transit.

The low income families have been victims of the dislocation of economic activity within cities. As urban blight has spread, larger areas of our cities house low income families At the same time, new industries furnishing potential jobs have been locating away from the areas of the city with high property taxes. Thus a fundamental barrier for the low-income individual seeking better em-

TABLE 3.3
AUTOMOBILE OWNERSHIP, 1960 AND 1970

Item	1960	1970
Automobiles in Use		
Per Capita	0.32	0.39
Per Household	1.09	1.27
Percent of Households Owning Automobiles	75.5	79.6
One Automobile Only	62.1	50.3
Two or More Automobiles	13.4	29.3
Percent of Households With No Automobile	24.5	20.4

Source: Automobile Manufacturers Association, Inc., *Automobile Facts and Figures*, 1968 and 1971. Data estimated by the Association from Census information.

TABLE 3.4
HIGHEST AND LOWEST CONCENTRATIONS OF NO-CAR HOUSEHOLDS, 1970

Characteristics	Percent of Households With No Car
ALL HOUSEHOLDS	20.4
HOUSEHOLD INCOME:	
Under $3,000	57.5
$15,000 and over	3.8
REGIONS:	
Northeast	27.5
West	14.9
RESIDENCE:	
Metropolitan	
In Central Cities	34.0
Outside Central Cities	12.2
Nonmetropolitan	
Nonfarm	17.5
Farm	12.8

Source: Automobile Manufacturers Association, Inc., *Automobile Facts and Figures*, 1968 and 1971. Data estimated by the Association from Census information.

ployment has been transportation. As Table 3.4 shows, over fifty-seven percent of the families without cars are those with incomes under $3,000. Of the no-car families, 44% live in metropolitan areas and 34% of these live in the central cities. These no-car families with low incomes are concentrated in the urbanized Northeast region. Table 3.5 shows the ownership of cars in our metropolitan areas. In New York City, over 41% of all families—the rich and the poor—have no automobile. The same holds also for over 27% of all families in Chicago, Philadelphia, Boston, and Pittsburgh. What is not shown is that the work trip has become so automobile-oriented that an automobile is an **expensive necessary condition** that most low-income families must bear if they are to earn a living.

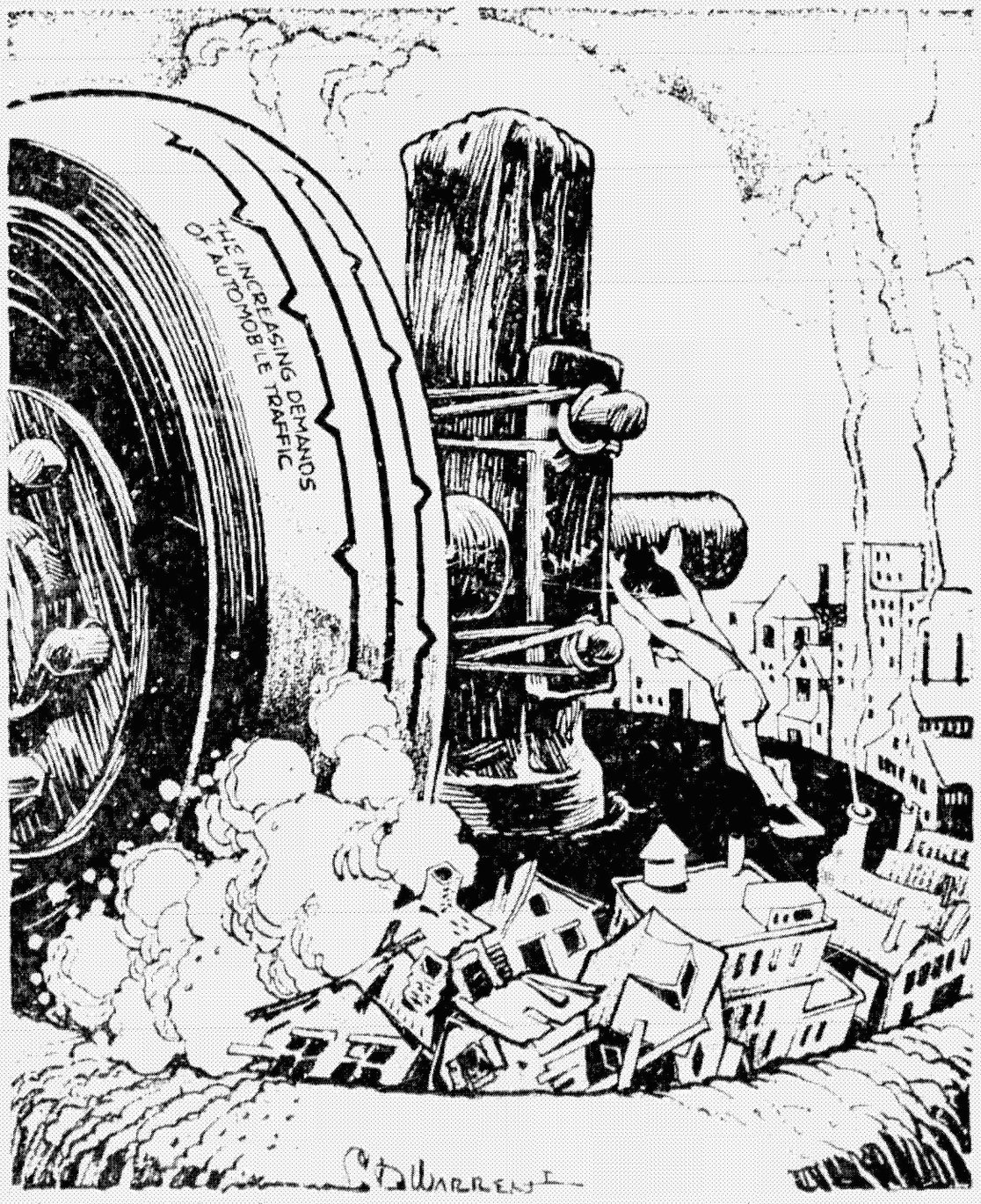
Thus, several factors are responsible for the relocation of economic activities which has made the automobile an attractive, if not a necessary condition of life. The cycle has been accentuated as public transit companies have increased fares, reduced service, and delayed maintenance. Even these economy measures have not sufficed to stave off the demise of privately-owned transit systems. Many city administrations are being rudely awakened to the problems of bus transit as bus systems have been dumped in their laps by defunct private companies.

The choices before these local officials are not easy ones. In the first place, the advantages given to the automobile by our land use policy, the Highway Trust Fund, and so on have reduced the profitability of other transit modes. This is not to say that public transit should necessarily "pay its own way." Indeed the figures we have shown imply important spillover effects of improved public transit such as improved work opportunity for the poor; and since such spillover benefits usually cannot be recouped by increased fares, subsidization of public transit is often justified. At the same time, however, local officials are beset with taxpayers' revolt, antiquated revenue systems (based primarily on the property tax), a fading tax base and, in

TABLE 3.5
OWNERSHIP OF CARS IN SELECTED METROPOLITAN AREAS, 1970

Standard Metropolitan Statistical Area	Percent of Households Owning		
	No Car	One Car	Two or More Cars
New York	41.2	40.4	18.4
Los Angeles-Long Beach	17.2	45.1	37.7
Chicago	28.3	50.0	21.7
Philadelphia	27.0	45.3	27.7
Detroit	15.5	48.3	36.2
San Francisco-Oakland	19.9	47.3	32.8
Boston	28.6	47.7	23.7
Pittsburgh	29.1	51.4	19.5
St. Louis	24.7	47.8	27.5
Washington, D.C.	24.5	44.5	30.9
Cleveland	19.0	47.9	33.1
Minneapolis-St. Paul	12.8	46.6	40.6
All Households	20.4	50.3	29.2

Source: Automobile Manufacturers Association, Inc., *Automobile Facts and Figures*, 1968 and 1971. Data estimated by the Association from Census information.



THE MILL GRINDS SLOWLY – BUT GRINDS EXCEEDINGLY FINE

Cartoon by L. D. Warren
Reprinted Courtesy of
The Times-Herald,
Newport News, Virginia

TABLE 3.6
OWNERSHIP OF BUS, RAIL, AND TROLLEY COACH SYSTEMS, December 31, 1959 through December 31, 1970

Year	Total	Private	Public
	Number		
1959	1,225	1,173	52
1964	1,152	1,073	79
1967	1,138	1,040	98
1968	1,094	980	114
1969	1,086	955	131
1970	1,079	938	141
	Change		
1959-64 (Average per Year)	-15	-20	+5
1965-67 (Average per Year)	-4	-11	+6
1968	-44	-60	+16
1969	-8	-25	+17
1970	-7	-17	+10
Total Change 1959 through 1970	-146	-235	+89

Source: American Transit Association Supplement to the 1970-71 *Transit Fact Book*.

general, a financial crisis for our cities. Moreover, as we have mentioned, most of our metropolitan areas are Balkanized into numerous governmental bodies which lack the breadth to tax and spend in ways which account for all costs and benefits.

Similar fiscal difficulties appear at the state level. Typically state legislatures have been controlled by rural and suburban interests. It is no wonder that state spending has not adequately attacked the transportation needs of cities. Actually, it is only the states who have authority to restructure the governmental boundaries of our metropolitan areas; but states have reneged on their responsibility to do so, and the problem of governmental boundaries remains a major bottleneck to planning and funding for rational land use and transportation. As Table 3.6 shows, private ownership of public transit still dominates numerically. However, the ownership of bus rail, and trolley coach systems has bee . declining. There were 146 fewer systems at the end of 1970 than at the end of 1959 but the number of privately owned systems had decreased by 235. Due to the take over of many private systems by local governments, there was a net increase of 89 publicly owned systems. Moreover, most of the large-scale transit systems are now publicly owned companies, and the latter haul over 80% of the bus, rail, and trolley passengers.

The Mix of Public and Private Ownership

In most technologically advanced countries the externalities, economies of scale, and the monopolistic characteristics of most transportation markets have called forth public sector ownership and operation. In the United States, the public sector has merely attempted to provide an environment in which most of the transportation system is privately owned and operated. Where investment has been grossly inadequate and where monopolistic pricing has been flagrant, the government has reluctantly stepped in. The regulatory structure which has evolved is very uneven. Price regulation usually attempts to provide a "fair return" on the capital of the

owners. Each agency has tended to act as **advocate** for the firms they regulate, but their efforts have been in some cases self-defeating due to the competitive advantage that some modes have gained over others. It is not easy to say whether the nature of competition or our regulation policies have been more important in causing the imbalance of investment in the different modes. The Department of Transportation has observed that: "Current regulation of entry of new firms into some transportation modes tends to protect existing carriers, including inefficient ones; present price regulation tends to distort the actual economic advantages that one mode may have over another for a certain type of traffic, and can, thereby, protect the less efficient service; and regulation which prevents abandonment of uneconomic services protects the users of those services. Such regulatory imbalance when coupled with investment imbalances partially explains the decline (relative at least to other modes) of urban public transportation and intercity freight and passenger service by rail." [56] Our present system features uncoordinated price regulation, limited market entry, a myriad of tax and spending schemes, and an assorted mix of private and public participation.

Our mixed system of transportation decision making has not been an "unmixed" blessing. The Department of Transportation itself has decried its effect on investment spending:

> "Whatever its jurisdiction, government spending, which finances capital investment in certain transportation facilities and subsidizes the operation of certain transportation services from general tax revenues, has distorted the calculus of costs and benefits on which the enterprise economy depends for the efficient allocation of resources. And correcting this aberration is likely to be difficult, since Government spending programs—once started—have often proved hard to terminate or redirect in the face of changing needs or public concern."
>
> ". . . one result of these distortions is that our 'mixed' transportation system appears to suffer from a serious investment imbalance as between modes and as between the public and private sectors." [56]

Who Is In Charge In Urban Transportation?

When we consider the myriad of Balkanized governmental units within our urban areas, it becomes obvious why no rational transportation planning emerges.

Most of our metropolitan areas feature large numbers of adjoining and overlapping governmental bodies which exercise spending power of some sort. These powers can often be translated into **veto power** over area-wide land use and transportation decisions.

Important **externalities** exist which transcend governmental boundaries. Both negative and positive externalities are created for adjoining areas by transportation decisions which influence the location of various economic activities. Often progress toward a more rational land use and transportation policy is impeded by the inability of governmental units to reconcile their conflicting interests.

The dynamics of economic development within metropolitan areas further erodes rational allocation of land and transportation. Moreover, the differences in property values, tax laws, and public services found in the separate governmental boundaries often tend to influence dislocation of economic activities in detrimental ways.

We have already noted the paradox that the locations of activities are more flexible than the transportation facilities we use to get from one place to another. In the first place, transportation vehicles and routes feature high **fixed costs**. In the second place, once a route is established, the location of economic activity along that route makes changing it difficult to achieve.

Studies by Julius Margolis have examined the continuous spatial shifting that occurs among the locations of residential and commercial activities within a metropolitan area. [57] The shifts which occur often cross the boundaries of governmental units. Those movements attendant to the "urban blight" phenomenon have lowered the tax bases in central city areas while increasing the demand for certain public services (such as public transit for the urban poor). Thus conflicts of interest among governmental units (and the individuals and businesses they represent) have been accentuated. Theoretically the parties should be able to make "trade-offs" which would reconcile their differences and at the same time provide

optimal land use and transportation policy. In the real world, however, the mechanisms for making these trade-offs do not exist. The actual benefits and costs (to include social as well as individual benefits and costs) cannot be appropriately accounted for in the incentive patterns of the individual firms and governmental units. Thus the economic and political behavior of these "actors" cannot be expected to produce optimal clustering of activities and attendant transportation facilities.

There are other sources of nonconcurrence between the interests of the community and the institutions that make transportation decisions. At the local level, zoning codes and urban redevelopment plans often better reflect the immediate interests of the wealthier property owners than the long-term interests of the average citizen who has few thoughts about the evolution of his community.

The value of land in urban America is significantly linked to the transportation system. Land values reflect the mobility of the population and of commodities. [58] Essentially the more accessible a particular location, the greater its value. Since transportation channels follow "narrow and fixed spatial" corridors, [59] their future locations should be assessed according to the impact they will have upon land values in the community. In general, the land value formula is a product of two location variables: (1) distance from central city or urban core; and (2) proximity to the flow of urban traffic. [60] Land has higher value if it is nearer the central business district and transportation artery; while land more distant from downtown and more isolated from the community by transportation, will have lower value. Being close to the "on" and "off" ramps will raise land values; being distant from them will probably decrease these values. [61] Amos H. Hawley argues that competition for land use sites is sensitive to "frontage on principal thoroughfares and proximity to secondary points of traffic convergence." [62]

Unfortunately, our political institutions are often more responsive to those organized around direct and immediate interests than those who are unorganized due to their interests being indirect and perhaps long term. In the case of transportation, those with direct interests are often those who own property and use their influence to have its value increased. Thus zoning codes tend to be changed whenever it becomes more profitable to use land for industry, commercial and multifamily residences rather than single-family residences, recreation, and parks. Similarly, road planning and spending are usually quite responsive to local business interests. Until recently the only conflict observed, was between developers of shopping centers and downtown business interests. Little thought was given to the effects economic development would have on the environment, the quality of life, and the life styles open to the average citizen.

Voters themselves tend to look at their own immediate wants rather than the social benefits and costs associated with long-term economic development. Since at any specific time, most of the land use and transportation variables must be taken "as given," voters tend to vote according to their own immediate interests, i.e., "what action will improve my drive from my home in the suburbs to my job in central city?" Individuals cannot easily visualize transportation and land use as a "system." If they are to participate as enlightened voters, they must know of the alternatives available for community development and be aware of the methods by which they may voice their opinions.

Considerable research and planning is required if decision-making processes are to be found to overcome the difficulties outlined above. At this point we suggest several approaches which may be followed:

A basic approach to the mismatch of governmental units and benefits and costs is to develop geographical planning districts whose boundaries accord with the benefits and costs generated by the economic development of the metropolitan area. As a rule this area would seem to conform roughly with the standard metropolitan statistical area (SMSA); however, where benefit and costs generation is not clustered along these boundaries others should be drawn. The final authority for drawing such boundaries should rest with the Federal Executive and Congress in coordination with states and localities. The states, which now have the responsibility for drawing the governmental boundaries of localities, have not fulfilled this task due to the political power of rural and suburban districts.

The efforts in recent years to develop planning districts have attempted to make them conform to the areas where significant benefits and costs are generated. However, these planning procedures do not adequately allow for general participation and the planning bodies have little power to implement. In

TRANSPORTATION POLICY

(1972 DOT Statement on Policy)

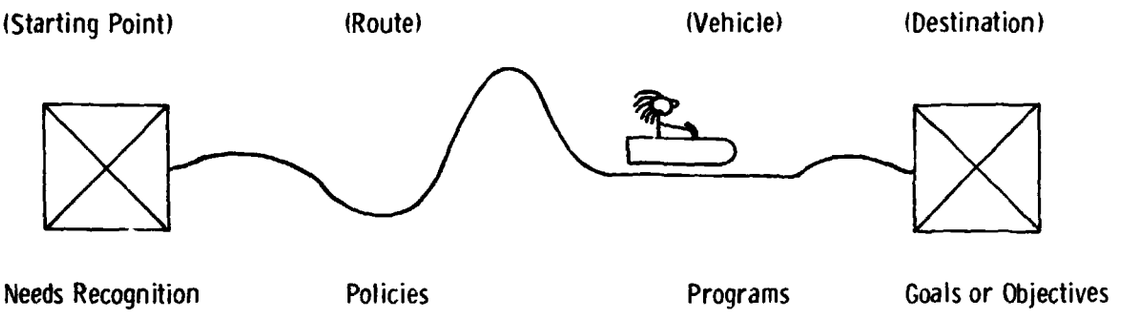


FIGURE 3.1

order for real decision-making power to be shifted to an **area** planning organization, there must also be a transfer of budgetary power as well. These planning organizations must be given authority to tax and borrow as well as to enact zoning codes.

Several approaches are available for overcoming the tendency of political bodies to respond more readily to those with direct interests—such as building roads to enhance the interests of large property owners—rather than to those indirectly affected—such as those whose "life styles" are only influenced by the long-run indirect effects of the transportation pattern. One approach is an extensive educational program to include both a greater emphasis in schools on how transportation is related to the growth and life of cities and more specific educational campaigns (to include public hearings, television seminars and debates and the like) in connection with the adoption and changes to land use plans for the community. The "ecology" movement has demonstrated that citizen groups can be effective in focusing attention on long-run indirect effects of our economic development. This focus can be extended to the question of how we use transportation and land use to give some direction to our economic and social development. The goals and guidelines upon which zoning and transportation plans are drawn would hopefully by oriented more towards improving the **quality of life** rather than improving certain property values.

Another method which may reduce the ability of special interests to manipulate zoning and transportation plans, is to utilize voting procedures which make these decisions "constitutional" in nature. Suppose, for example, that the adoption of a long range community development plan requires a two-thirds majority of a popular vote and any changes require a three-fourths majority of the duly-constituted planning organization. Although this approach reduces flexibility, it has the advantage of reducing the ability of special interests to manipulate zoning and transportation plans for their own benefits.

Part of the problem, as we have mentioned, is that immediate interests of **voters** as well as special business groups may be those which govern transportation and land use decisions. It is assumed here that the narrow perspective can be mitigated when enlightened voters are allowed to participate in **long run** plans for community growth.

National Transportation Policy

Do we have a National Transportation Policy which is identifiable, viable, and capable of supplying need direction for transportation planning? To explore and answer this question, it is necessary to define the word "policy."

Webster's Dictionary defines policy as:

> "a definite course of method of action selected, as by a government, from among alternatives and in light of given conditions to guide and determine present and future decisions."

The substance of this definition is that "policy" is a thoughtful and well reasoned plan devised after considering and weighing alternative courses of action. In a transportation context, it would surely have to be a multi-modal or inter-modal plan.

The Department of Transportation, in its 1972 statement on national transportation policy, made the following useful analogy to describe policy:

> Government by policy can best be described in terms of an analogy particularly appropriate to transportation. If we think of goals or objectives as destinations, and programs as vehicles, then policies are the routes upon which the vehicles travel to the destinations (goals). The factors which determine the particular characteristics of the routes chosen are the criteria for policy. Without routes it is hard to determine the distances to goals, what obstacles stand in the alternate routes to the goals, or whether the vehicles in question are at all suited for the journeys. [63]

This trip analogy is depicted in Figure 3.1. We have added a starting point, which has been labeled "Needs Recognition."

When we speak of policy in this sense, it is clear that we must look to laws passed by Congress. Although the executive branch of government, and in particular, the Department of Transportation, has the important function of formulating and recommending transportation policy, it is Congress that establishes policy by passing enabling statutes for particular transportation programs and specifying requirements for transportation planning.

In the sense that "policy" is thus defined, we do not have a national transportation policy. This is clear from the Department of Transportation's two recent statements on national transportation policy, the above mentioned 1972 statement and its predecessor which was issued in 1971. [56]

The point is made quite effectively in the 1972 publication:

> This nation has never had the capacity for integrated governmental multi-modal or inter-modal transportation planning. The orientation of present federal programs toward a single mode has led to drastically different criteria and procedures for resource allocation among the various modes.

There are, of course, general statements of policy, such as the charge to the Department of Transportation to develop:

> "national transportation policies and programs conducive to the provision of fast, safe, efficient, and convenient transportation at the lowest cost consistent therewith and with other national objectives, including the efficient utilization and conservation of the nation's resources." [9]

Such statements are of questionable value. No one would seriously advocate slow, unsafe, inefficient and inconvenient transportation at a high cost. They merely state the obvious without giving concrete direction. Thus, the modal programs have predominated in shaping our transportation planning.

The effects of this lack of policy have been substantial. A case in point is the situation which now exists in urban areas with respect to highways and public transit. In citing this example, we are not attacking highway construction as such, suggesting that highways do not have a vital role in an urban transportation system or advocating that public transit is a cure-all for urban transportation problems. We are merely attempting to demonstrate the results of single mode programs.

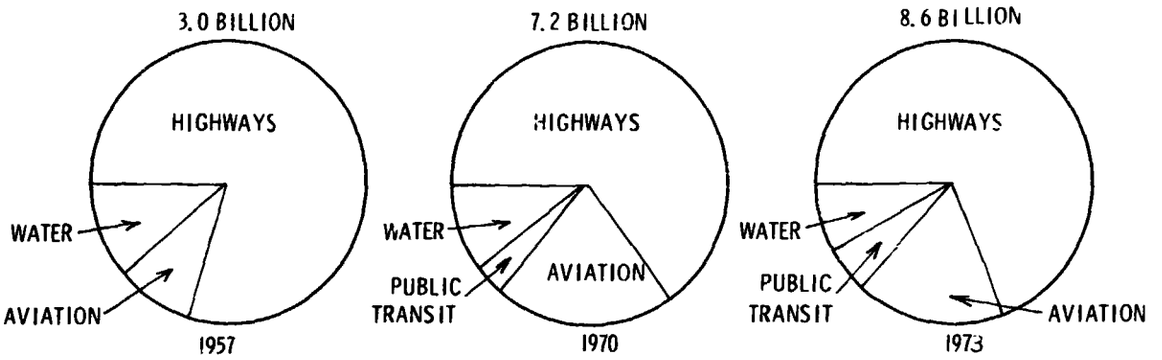
In 1956, Congress decided to fund a massive highway construction program. The Highway Trust Fund was created to finance highway construction through the method of user taxes. Since 1956, highway programs have received the major share of federal transportation expenditures. Figure 3.2 shows relative expenditures for the years 1957, 1970, and 1973.

Between 1950 and 1970 our nation's population grew from 151 million to 203 million, an increase of 34%. [64] Most of the increase occurred in the urban areas. During the same period, highway travel has increased 145%. [64, p. II-49] Urban highway travel, which now exceeds 50% of the total, is increasing at a higher rate than rural highway travel. [64, pp. II-7-8]

For urban areas, the results have been:

1. auto-oriented urban development patterns
2. congestion
3. pollution

FEDERAL EXPENDITURES **FIGURE 3.2**



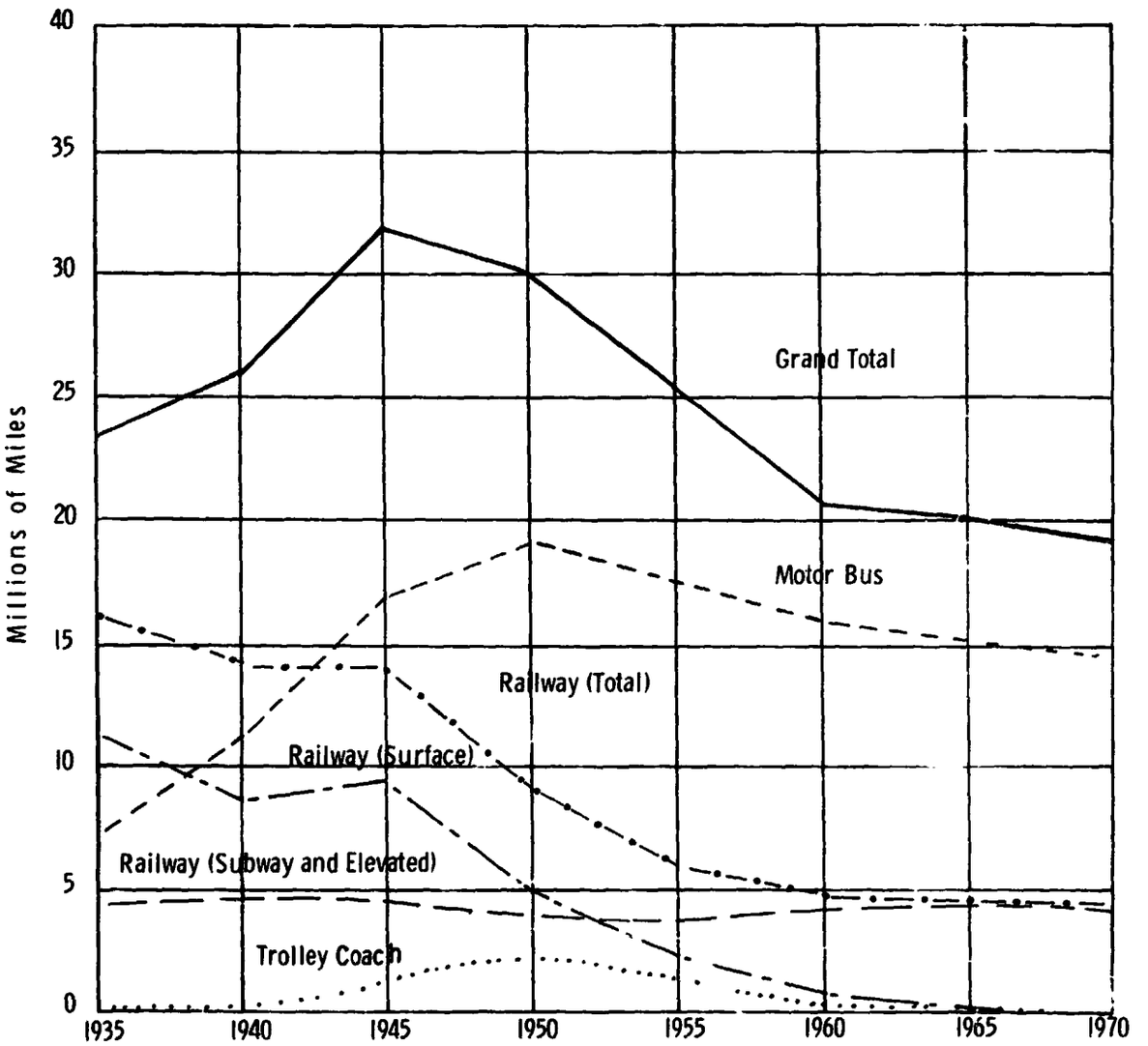


FIGURE 3.3

TREND OF VEHICLE-MILES OPERATED

Source: *1969-1970 Transit Fact Book*, American Transit Association

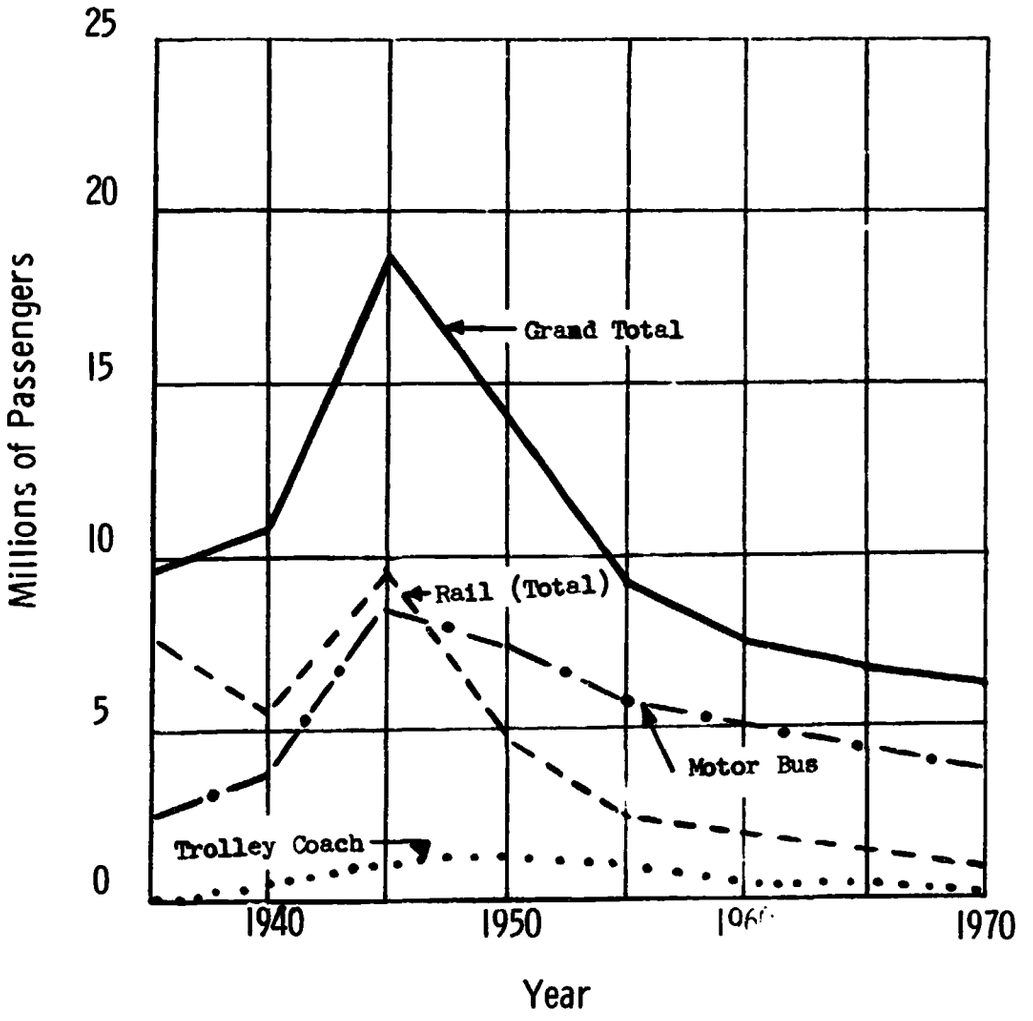


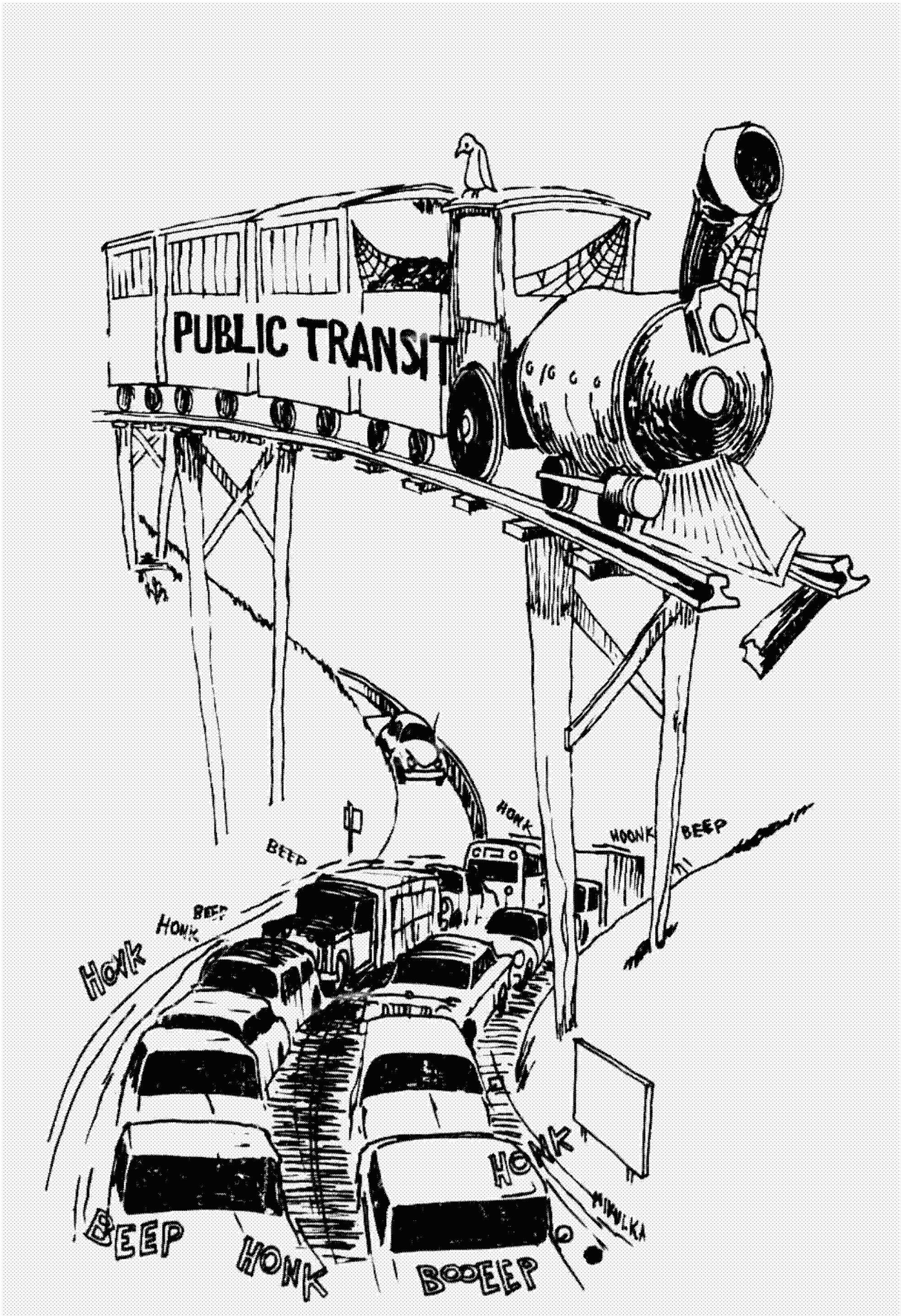
FIGURE 3.4
TREND OF REVENUE PASSENGERS
Source: *1969-1970 Transit Fact Book*, American Transit Association

4. neighborhoods and parks dissected by highways
5. the alteration or destruction of the esthetic qualities of many scenic areas; and
6. lack of mobility for people without automobiles, especially persons in disadvantaged areas of our cities.

The McCone Commission, which investigated the 1965 Watts riot, concluded that isolation of the ghetto by highways and lack of public transportation contributed to rebellion.

> Our investigation has brought into clear focus, the fact that the inadequate and costly public transportation currently existing throughout the Los Angeles area seriously restricts the residents of the disadvantaged areas such as south-central Los Angeles. This lack of adequate transportation handicaps them in seeking and holding jobs, attending school, shopping, and in fulfilling other needs. It has had a major influence in creating a sense of isolation, with its resultant frustrations, among the residents of south-central Los Angeles, particularly the Watts area. [65]

In the meantime, what has happened to


PUBLIC TRANSIT
BEEP
HONK
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urban public transit? By any measure, it has declined dramatically. Vehicle-miles operated (Figure 3.3) and revenue passengers carried (Figure 3.4) decline each year. While revenue passengers have been decreasing, the plight of public transit has been worsened by the necessity for increased fares (Figure 3.5). The inevitable result of these trends is an ever-widening gap (deficit) between operating costs and operating revenues (Figure 3.6).

A number of factors have been cited as causes for the decline in public transit, including growth in personal income making possible increased ownership of automobiles and suburban homes, federal policies making home ownership easier; development of extensive highway systems; and the failure of public transit to serve the changing needs of people and serve their mobility requirements. [66] The suggestion that public transit was unable, or that its management was unwilling to respond to urban needs is subject to question. It was never given a fair chance.

The disparity in treatment between highways and public transit from the standpoint of federal expenditures speaks for itself. It was not until the passage of the Urban Mass Transportation Act of 1964 [67] that Congress recognized that a public transit crisis had developed. It was not until six years later, with passage of the Urban Mass Transportation Assistance Act of 1970, [63] that sufficient federal money was made available to do anything about it. Congress pledged to spend $10 billion on public transit over a twelve-year period. This action is a step in the right direction. However, it is a relatively small amount when compared to highway expenditures.

This imbalance of treatment has, at least until recently, excluded public transit as a possible solution to urban transportation needs. With substantial federal funds available for highway construction and little or no federal help for public transit, it is no wonder that cost-conscious urban planners built highways and ignored public transit. This situation is summarized in a recent article dealing with highways and the urban poor.

> The highway program, of course, is a very large factor in the urban transportation problem in the inner-city. Highways are choking inner-city streets with traffic, enticing transit riders into their automobiles for commuter purposes and thus killing transit companies, and consuming billions of dollars each year that might be more efficiently used for mass transportation. Today, because

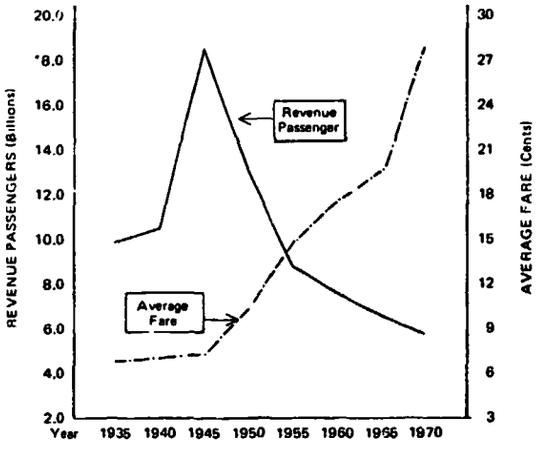


FIGURE 3.5
AVERAGE FARE/
REVENUE PASSENGER
1935 - 1970

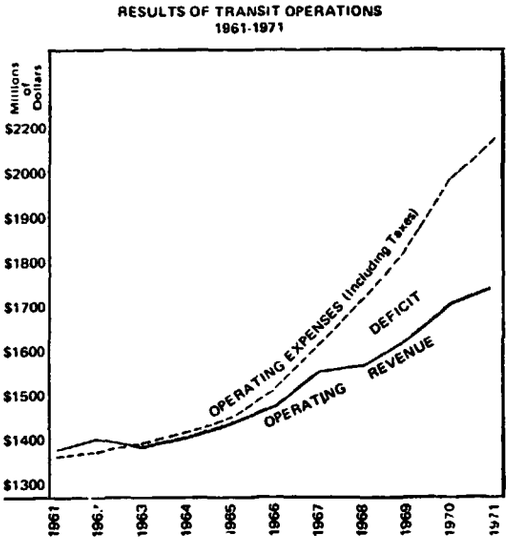


FIGURE 3.6
RESULTS OF
TRANSIT OPERATIONS
1961 - 1971
Source: *1971-1972 Transit Fact Book*, American Transit Association

of the nature of highway funding. "Cities and states will build more superhighways simply because the federal funds are available to them for highways. If they do not build highways, they will lose the funds." Thus, the issue for cities today is not what mode of transportation is best for their varying needs, but only where to locate (or not locate at all) a freeway. Cities have diversified needs. The present system provides a highway-only answer. [69]

In 1970, Mayor Sam Massell described the plight of the Atlanta Metropolitan area, due to auto-oriented development, in the following manner:

> Our five-county metropolitan area had 465,000 registered motor vehicles in 1962, when the need for rapid transit was recognized. By 1968, when we held a referendum, this number was 602,000. Today we have over 800,000 and, left to grow without a competitive means of transit, they will surely strangle my city. Not only are congestion and all of its aggravations bringing the city to a standstill—like the 15-minute period between 7:45 and 8:00 in the morning when we have 14,000 cars trying to move in the heart of downtown—but more than 50% of the land in the central business district is now dedicated to the movement and parking of automobiles, and the latest figures report that 81% of all pollution in Atlanta comes from motor vehicles. [70]

Even a prime beneficiary of highway construction and ever-increasing automobile usage, Mobil Oil Corporation, has called for a review of our modal funding programs. On July 20, 1972, Mobil ran an advertisement in *New York Times* entitled, "Let's get moving with a National Master Transportation Plan." That advertisement is printed in full on the following page.

The reality that public transit can be responsive to urban needs has been shown by the Shirley Highway exclusive bus lane experiment for commuter travel between Washington, D.C., and suburban Virginia. The success of the experiment has exceeded everyone's expectations.• Stimulated by a proper mix of federal aid and ingenuity, public transit can play a vital vole in meeting the mobility needs of people.

Why don't we have a well-reasoned national transportation policy? The following statement made by former head of the Bureau of Public Roads, Thomas H. McDonald, more than twelve years ago goes far toward answering this question:

> Any problem becomes difficult of solution if it is not understood. This is particularly true of transportation. There is a widespread fallacy as to the true nature of transportation, and this failure to appraise transportation correctly is the basic cause for many inadequate laws and regulations. Problems of fact confused with problems of value lead to wrong decisions and policies.
>
> Problems of equity among the modes of transport, the attainment of excellence in service, and the realization of maximum public utility require for solution a definition of the true nature of transportation with the appraisal accepted as a principle of public policy.
>
> Transportation has a basic dual nature.
>
> This is true without exception, and whether applied to a single mode of transport or to a combination of two or more modes.
>
> The dual nature of transportation consists of two components: (a) service, and (b) power. The second—the power component—has been generally ignored in the formulation of public policies and legal mandates. These have traditionally rested upon the premise that transportation is a service only. [71]

We believe that there are two basic reasons for the lack of policy. First, there is a lack of appreciation for, and understanding of, the full potential which transportation has to offer. Second, transportation has not been assigned a role or function in our scheme for social and economic development.

As stated by Mr. McDonald, transportation has two fundamental aspects—service and power. There has been a lack of understanding of the full potential of its service aspect, and a failure to recognize, harness, and exploit its power.

Traditionally, transportation has been viewed as a business which should be privately owned and operated under the incentive of profit. Typical of this viewpoint is a

Let's get moving with a National Master Transportation Program.

Anyone in America who rides trains or buses or subways, or uses public transportation to get in and out of airports, knows our mass transit is pitiable.

More and better mass transit could ease traffic jams, reduce air pollution, and conserve energy fuel. And make moving around a lot more civilized.

To achieve this, as we suggested in this space on October 19, 1970 ("America has the world's best highways and the world's worst mass transit"), we must have new and vastly better mass transit systems.

Instead of dealing with highway construction, railway needs, urban transit, airport improvement, and maritime requirements in separate pieces of legislation, we should approach them as part of an overall transportation plan. This would tie all forms of transportation together to move people and goods fast, safely, comfortably, on time, and at reasonable cost.

To carry out that plan, Congress should enact a National Master Transportation Program. The money should come from direct Congressional appropriation, based on clear and rational priorities. In the process, the Congress should review all special earmarked funds, including the Highway Trust Fund.

Mobil supported the Highway Trust Fund when it was enacted in 1956, as a logical way to raise and husband the money needed to build the Interstate Highway system. Now we believe a new look is needed at the whole question of transportation and transportation funding. Such a review may show that special earmarked funds are no longer the best possible approach.

Indefinite continuation of the Highway Trust Fund could deter construction of more-urgently needed non-highway transportation facilities. Indefinite continuation also would encourage expansion of the fund's goals at a time when they ought to be cut back.

Completion of the Interstate Highway System should be reviewed. It now is apparent that some sections of urban areas (lower Manhattan, for instance, and South Philadelphia) would cost $20 million per mile to complete. It is not at all certain that the benefits from these sections would justify the outlay.

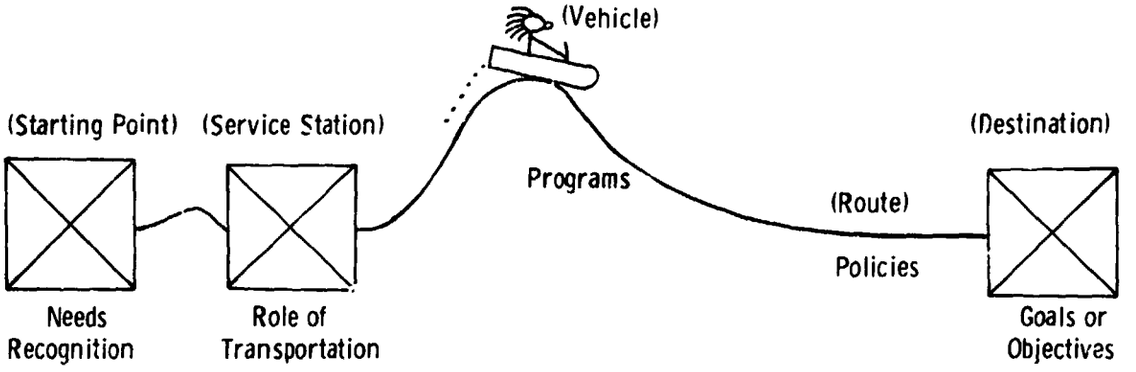
Highways are important to us, obviously. Highway travel builds sales for Mobil. But traffic jams, and a glut of cars using too much gasoline to haul too few passengers, waste many resources, including oil.

We want our products to help more people get where they want to go, with greater ease and less waste than is now possible.

In our view, that requires the establishment of a National Master Transportation Program as soon as possible.

Courtesy of Mobil Oil Corporation

FIGURE 3.7
TRANSPORTATION POLICY



statement made by President Kennedy to Congress in 1962:

> This basic objective can and must be achieved primarily by continuous reliance on unsubsidized privately-owned facilities, operating under the incentives of profit and the checks of competition to the maximum extent practicable . . . to the extent possible, the users of transportation services should bear the full cost of the services they use, whether those services are provided publicly or privately. [72]

This type of concept has tended to minimize transportation's potential for providing service. Transportation services which people require as a matter of basic necessity, cannot always be provided on a profitable basis. Under private ownership, when business incentives are not present, there are no incentives to provide service. pf p. 31.

Over the years there has been a gradual shift from private to public ownership of public transit systems. [66, pp. 29-30] This trend has accelerated since 1965. In 1971 public transit systems accounted for more than 80% of all revenue passenger and operating revenues. [73] This trend has been caused by economic distress within the industry. This suggests that, at least for the present, private ownership is not feasible in all cases. The special interest which a metropolitan area has in public transit may require public ownership. [74]

The power of transportation as a tool for land use planning has been generally ignored. We have, in fact, permitted that power to rage unchecked to the detriment of our economic and social values and the environment. If transportation is used as a tool for rational land use planning, the social, economic and environmental benefits should be such that its performance need not be judged on the basis of the fare-box alone.

The need for land use planning has been discussed in Chapter 1. The National Land Use Policy and Planning legislation which is pending before Congress, offers great promise for the future and a vital role for transportation to play in our national development.

It is projected that our nation's population will increase another 50 million (to 253 million) by 1990. Our land area will, of course, remain the same. In addition, our nation is now more mobile than ever before. Previously remote land areas have become more accessible. Our freeway system permits us to drive anywhere in the continental United States within a few days. By plane we can be there in hours. The land use implications of these factors are obvious. We cannot permit the unplanned sprawl and blight which has afflicted our urban areas to afflict our nation as a whole. The answer is comprehensive and effective national land use policy and planning. With a balance of land use planning and transportation planning, the day may come when transportation is routinely used to avoid, rather than solve, problems.

We have made one more addition to the diagram the Department of Transportation's policy analogy (Figure 3.7). The missing link in the formulation of transportation policy—the role of transportation--has been added. We recommend transportation be given a dual role in our scheme of national development: as a service to provide people with necessary mobility; and as a tool for land use planning

and desirable social and economic development.

Conclusion

We would like to conclude the chapter on an optimistic note. President Coolidge once said: "It is not so much where we are, but where we are going." [74, p. 81] This remark seems appropriate here.

We are now in a better position than ever before to establish a flexible and workable national transportation policy. Within the past decade we have become aware of the so-called "indirect" undesirable side effects of transportation systems. We are also beginning to take a more realistic approach toward assessing the real costs of particular modes of transportation. The following statement, in the Department of Transportation's recent study on the feasibility of mass transit subsidies, is indicative of this awareness;

> "Current cost characteristics of the automobile tend to place it in price competition with transit, since the perceived cost is largely the out-of-pocket cost of daily operation plus parking fees (the original capital cost, insurance, and major occasional repairs and replacements tend to be ignored in choosing between the auto and transit for local trips).
>
> Beyond this, moreover, there are substantial costs associated with auto usage, especially for peak period commutation, that are not borne by the user at all. The consequence of the existence of these external costs is a substantial underpricing of the auto mode relative to transit. Prominent among these external effects are both the direct and indirect costs of urban expressway construction, particularly when an effort is made to design such expressways with sufficient capacity to meet peak hour demands. There is widespread agreement among economists who have studied urban transportation that the user charges (primarily gas taxes) incurred by peak period users of such facilities do not, in fact, cover the increase in costs associated with providing the extra lanes needed for peak loads. But land acquisition and construction costs for urban freeways are not the only auto commutation costs not fully paid for by users. Even if residential relocation costs are fully reimbursed (and frequently they have not been, although the Uniform Relocation Assistance and Real Property Acquisition Policies Act of 1970 and the Federal-Aid Highway Act of 1970 have now brought much-needed relief), the intangible costs of disrupting established communities and living patterns can be enormous, not to mention the impact of noise on residents and activities that are not relocated. In addition, air pollution (largely from automobiles) has become a problem of endemic proportions in our major urban areas and represents an incalculable cost generated, but only partially borne, by automobile users." [66, pp. 26-27]

There is, however, a need for greater awareness by the public and transportation planners of these costs to guide them in making choices between modes of transportation. Federally sponsored education campaigns, like those relating to drug use and cigarette smoking, would be appropriate for this purpose.

In formulating policy, it will be necessary to re-evaluate traditional approaches to transportation which have inhibited the maximum use of its potential and have left transportation systems badly out of balance. For example, modally designated trust funds must be eliminated to permit flexibility for intermodal policies, development and planning; and public transportation should be regarded as an essential service with emphasis on satisfying human needs, rather than on keeping the operation self-supporting at the fare box.

Transportation policies and planning must be responsive to coordinated national, state, and local goals for social and economic development, rather than reactions to anticipated travel demands. However, transportation cannot foster and serve desirable development without comprehensive land use policy and controls which are coordinated at all levels. Local governments cannot continue to make decisions with respect to zoning and transportation solely on the basis of market demands and land values. Adequate recognition must also be given to non-economic goals.

The federal government must assume the responsibility for overseeing the establishment of land use and transportation policies at all levels. The problems in metropolitan areas can no longer be regarded as local in nature. The federal government must assume a role of leadership, but not dictatorship, in promoting measures to ease congestion and promote balanced planning. Examples of areas where leadership is needed are: the elimination of restrictive state laws and ordinances, such as those establishing state highway trust funds [75] and prohibiting jitney operations, which curtail planning flexibility; and banning or restricting the use of private automobiles in congested central business districts. [76] We need new policies and new governmental structures so that lasting solutions can be devised for our land use and mobility problems.

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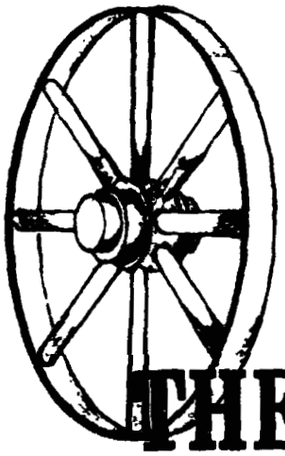

4

THE ENVIRONMENTAL COST of MOBILITY

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"Everything has its price."

That statement probably has been used to justify half the minor decisions and all the major decisions made by men. Caveat Emptor! Yes, buyer beware, for whenever we say that everything has its price, we usually mean that the item we are interested in is expensive, and no one knows exactly how expensive or why it is so expensive.

The product we are interested in is mobility—the cost; well, that's the subject of this chapter. The basic problem with the cost of mobility is that it is not posted. This chapter is not going to generate a cost tag either. What will be examined, however, are those many factors including pollution, energy, and land use which contribute to the cost but are not reflected necessarily in the posted price tag. To clarify: the cost is what is really paid for a product or service while the price is what one thinks he is paying. Ideally everyone would like the cost/price ratio to be less than one. For mobility and its requisite transportation, this is not so. The reasons behind why the cost is not reflected in the price form the central subject matter of this chapter.

4.1 Dollars and Sense

The cost of transportation is large. Recall that a full twenty percent of the Gross National Product is transportation related, and that cost is expected to climb higher in the future. As we near shortages of materials and resources, it is proper that each use of scarce commodities be examined. Energy is one of those resources in short supply. " . . . use of electrical energy for transportation is forecast to double by the year 2000, and transportation alone by that time is expected to use about one-fourth of the total energy consumed." [1] The "price" is the price of that twenty-five percent of the energy. The cost, however, is the price plus the losses to society incurred by not using that energy for other purposes. Specifically, focus upon our use of petroleum; it is refined for gasoline, aviation fuels, oils and lubricants, etc.—energy. However, petroleum is also used in one form or another in various plastics or polymers—production. What is used for energy cannot also be used for production.

What about the prices that people pay everyday? Consider that the average automobile is driven 12,000 miles each year and the average cost (including depreciation, gas, oil, maintenance, license fees, taxes, insurance, tires, etc.) per mile is 12c; then the expense of using your own automobile amounts to about $4 per day, each and every day of the year. On the other hand, public transit is also expensive. For example, at a dollar per day plus $6 a year for trips and taxi use, the bill comes to about $3 per day for each and every day of the year. That is not much until one looks at the per year cumulative difference of $360.

Another segment of the transportation cost is time. One of the many complex causes of suburban growth has been the lower cost of attractive, new housing. Typical savings on a suburban home over a more locationally convenient urban home can amount to between eight and ten thousand dollars. That's the price—what about the cost? Recall that the new suburban home is further away from the job than the more expensive but closer to the job home. Consider that the suburban home location results in a twenty-minute-longer commuter trip. (The U.S. National Average total time for the trip to work is thirty minutes.) Then if we allow $5 per hour for the commuter's time, the total twenty-year cost for time is $16,000. He still has to pay for the use of the car—possibly a second car. If the additional one-way distance is ten miles, the car costs amount to $12,480. Add the time costs to the car costs and the total additional cost is $28,480.

In summary, in order to save ten thousand dollars on the price of a home, the suburbanite must spend twenty-eight thousand dollars on transportation. The net savings actually amounts to a loss of eighteen thousand dollars.

4.2 What Are We Getting for our Money?

The answer is that Americans are receiving a great deal from their transportation dollars. We have one of the finest highway systems in the world. The per mile costs are lower than any other highway system requiring stop-and-go traffic. For example, a town study concluded that a single stop and start used as much tire rubber as a mile of average driving and as much gas as one-eighth of a mile [2]. Also our system of major airports, commuter airports, and private airfields is impressive.

On the other hand, there exists an increasing doubt as to whether or not we are getting nearly as much out of our trans-

portation expenses as we could or we should. We see our railroad right-of-way rusting before us, and yet there appears to be an almost daily increase in truck traffic on the highways. The Corps of Engineers spend a large part of their budget ($500 million per year) dredging and making new waterways, yet the barges which use them do not pay any tax on the gasoline they consume [1, p. 256]. Our cities have no room for their increasing population, yet we condemn housing to make way for roads and airports to bring yet more people into the city. Daily shipments are made into our cities of food, building materials, clothing, metals, chemicals, and the like, while all the cities seem to export in quantity is air pollution and polluted waterways.

Something is out of balance; and in any closed system, imbalances cannot exist for long without endangering the very existence of the system itself. The key parameters to these imbalances are (a) growth, (b) transportation as an urban designer, and (c) pollution.

4.2.1 Growth—A Case in Point

Following the manufacturing deprivations of the Second World War, many cities found themselves caught up in an unpredictable demand for automobile traffic. Cleveland was one of them. In the early 1950's a consultant [3] provided the county engineer with these grim statistics:

1. Every major arterial highway and road in the area was operating at a peak load of 100 percent of their design capacity.
2. 1950 population was 1,300,000 persons. By 1975 there would be 1,700,000 people.
3. Extended rush hours to cover a larger portion of the 24-hour day was only an immediate solution.
4. Future traffic would double in 20 years—the only way to solve this was to build freeways to sort out short trips from high-speed longer trips.

Construction began and traffic increased. In fact the population projection figures proved to be too conservative by 15 years. The 1,700,000 population was actually reached in 1960 instead of the projected day of 1975. Some of the causes for increased traffic and increased growth can be traced in part to the freeway building program itself.

A growing number of planners and urban designers are reaching the hard realization that there are internal relationships between the demand for transportation and those steps taken to meet that demand. Furthermore, this internal relationship possesses at least one segment operating in positive feedback—that is, the more one tries to meet the demand the harder it is to meet. In simple terms, we have, under the present conditions, a transportation/demand spiral.

4.2.2 Pollution: Overhead of or Overuse of Transportation

It is perhaps the pollution aspect of transportation that is most familiar to the reader: air pollution, land pollution, noise pollution, scenic pollution, and more. He is acutely aware of the contribution of the internal combustion engine, the unsightliness of the automotive junk yard, and the despoliation of the sea and shore accompanying every major oil spill. The erosion damage resulting from a poorly planned highway is unsightly as well as dangerous. And, what of the scenic views missed by travellers because certain commercial interests insisted that interstate highway grades be kept sufficiently low in order that trucks and buses are able to squeeze that additional fraction of a mile from every gallon of diesel fuel? What of the vapors lost during the fillup of an average automobile gas tank? In addition there is noise pollution. Noise that ranges from the incessant rumblings of a major roadway, to the raw screech of rail flanges upon improperly designed track, and on still more to the shattering roar of an airport too close to habitable living spaces.

But the environmental costs do not end here. They include the damages done by the extractors of valuable raw materials from the surface of the land and from within the depths of the land. Added to this are the costs of communities fractured by poor location of grade separated roadways. Patterns of daily living in closely knit communities are altered so that strangers could pass through their midst at speeds so great that the faces of the vehicle occupants are not even visible.

Human factor design plays an important role in pollution control also. For it is people who must live by, work on, and use systems of transportation. These systems must be environmentally and aesthtically sound as they are engineeringly sound. Good design is not "either/or," but must include a full measure of

both. What follows is a discussion of the environmental impact of transportation and the role of law in its protection.

A. Highways and Automobiles

> Our highways have proliferated with frightening speed, destroyed much of our cities, and defaced much of our open spaces. Already we have more than 3 million miles of paved roads (one mile for each square mile of land), and still we are told we must build more freeways in order to escape today's constant traffic jams. To the obvious environmental costs of such proliferation are added a host of less well-recognized social costs—widespread dislocation of people and businesses, wholesale destruction of valuable park land and wilderness, ever-increasing volumes of noise, and a mounting death toll that makes our most common mode of travel also our most deadly one. [4]

The potentially adverse environmental impacts of highway construction are numerous and well-documented, especially with respect to the urban freeway. The construction of new highways diminishes urban open space and may also require the taking of public parklands and playgrounds. Highway construction may also offend aesthetic values by causing the loss of neighborhood indentity. If a new highway severs a neighborhood, it presents a physical barrier to social interaction as well as establishing a psychological and visual barrier. Highway construction may also result in the displacement and relocation of significant segments of neighborhood population. The displacement of the urban dweller often has a heavier impact upon minority groups than others. Injurious displacement of businesses and farms may also be a consequence of a new highway. Within the urban environment, the highway right-of-way may require the condemnation of large amounts of taxable property, thus decreasing the city's tax base and increasing the burden upon the remaining land-owning taxpayers. The resulting automobile traffic will increase the level of noise pollution affecting adjoining landowners. Adverse ecological effects may result from the design and construction of highways in relation to streams and water resources. Cut and fill operations which straighten water courses and alter the drainage pattern of stream basins may affect fish and wildlife areas.

> Construction of suburban arteries can easily be justified as a short-range solution to pressing problems of congestion. Yet it can also spur new development far from the city core, reward land speculators, create a need for more public services, destroy natural areas, dump more cars into the central city and promote a pattern of suburban settlement that nearly precludes mass transit. [5]

The automobile-highway system also is responsible for a most significant adverse environmental impact with respect to air pollution. Automobile emission pollutants which contribute to the national air pollution problem consist of carbon monoxide, hydrocarbons, nitrogen oxides, particulate matter, and sulfur oxides. Automobile vehicles account for 90 percent of all carbon monoxide, 60 percent of the hydrocarbons, 50 percent of the oxides of nitrogen, and virtually all of the lead emitted into the atmosphere. [6]. Compliance with the Federal Emission Standards for automobiles requires control of the sources of vehicle exhaust emissions. All of the carbon monoxide, nitrogen oxides, lead compounds, and 60 percent of the hydrocarbons come from engine exhaust. The remaining hydrocarbons come from the crankcase and evaporation from the fuel tank and carburetor.

The automobile contaminants cause a variety of environmentally harmful effects. Each of the emissions pollutants is hazardous to human health and welfare. For instance, carbon monoxide interferes with the oxygen-carrying ability of the blood and is related to coronary heart disease [6, p. 17]. Lead is recognized as toxic to humans and may impair the maturation and development of red blood cells [7]. Furthermore, the health hazards caused by **all** air pollution are directly attributable to automotive emission pollutants (which represent more than 60 percent of the total air pollution). Air pollution can have substantial harmful effects upon vegetation. Crop losses due to air pollution are estimated to be between six and ten million dollars annually in California [7]. Expensive property damage also results from air pollution. According to the 1966 estimates of *The Mayor's Task Force on Air Pollution*, air pollution in New York City costs the residents one-half billion dollars per year for cleaning and maintenance of clothes and property

From a still broader perspective, the adverse environmental impacts of highway construction extend far beyond the destruction of open land and matters of wildlife preservation. The Highway Trust Fund, which requires the states to earmark gas and oil tax revenues for highway construction, occupies an adversary position to the environmental protective legislation passed by Congress. "More roads have inevitably led to more automobiles which in turn clog the roads, while producing more tax revenue to fill the inevitable demand for more roads. The consequence is not only the destruction of environmental values of the countryside but also substantial air pollution problems, major solid waste disposal from abandoned automobiles, and an enormous drain on natural resources for the manufacture of more and more motor vehicles." [8, § 9.01, p. 9-2]. The Highway Trust Fund does not pay for these costs. Environmental considerations aside, however, it must be recognized that the self-perpetuating nature of the automobile-highway system reflects the fact that a major portion of the national economy is dependent on automobile production—which is closely related to the availability of highways.

B. Airports

The construction of a major airport can cause large-scale despoliation of the environment. The obvious adverse environmental effects are aircraft noise and potential air and water pollution hazards related to airport operation. Airports occupy large tracts of land and their location may have significant consequences on the ecology of the surrounding area. For instance, to satisfy the requirement for large areas of flat and open land, landfill operations may be planned which destroy ecologically important land with wildlife and water fowl. The construction of an airport also ruins the potential of surrounding areas for many other uses. Secondary effects will be evident in new communication and transportation patterns, and changes in population distribution. An airport will have important ramifications on the use of roads in the area and cause congestion of access highways. In general, airports diminish the quality of life in their surroundings. However, any attempt to solve the environmental problems must also recognize the broad implications of a major airport as a component of the national and international air transportation system.

General Electric Photo—Erie Plant

C. Railroads

A discussion of the current adverse environmental impacts of railroads consists chiefly of a consideration of the need and value of existing rail facilities in the context of the congested, urban environment. A re-evaluation of existing railroad stations, yards, and rights-of-way is necessary to determine whether these properties may perhaps be more beneficially utilized for either urban redevelopment or some other improved means of transportation.

4.2.3 The Law Functioning In the Protection Of the Environment

A. A Background of Approaches to Solve Problems of Adverse Effects Upon the Environment

The issue regarding the preservation of the environment appears in the law historically in early cases of torts and nuisances. However, the law of nuisance as developed by case law was concerned primarily with the principle of a balancing of the equities in determining the rights of private litigants. That is, the economic benefit was balanced against the harm and discomfort caused by a particular activity. In addition to private nuisance suits concerned with the protection of the environment, the historical basis for governmental regulation of the environment lies in the exercise of the police power to protect public health. But most regulatory law developed prior to the twentieth century was not addressed to environmental protection but rather was intended to serve other narrow purposes.

Thus, until recent environmental legislation, the important legal actions to specifically afford environmental protection were the (1) nuisance and trespassory actions, and (2) actions by riparian property owners for interference with rights to water of undiminished quality and quantity. The question remained whether the public interest had been insufficiently taken into account in deciding environmental issues. A lack of understanding of the pollution problem was indicated by the traditional focus on effects, rather than on preventive procedure. The need for enlightened environmental regulation became evident with an increasing awareness of two serious problems: (1) the amount of pollutants had grown to hazardous quantities; and (2) the capacity of certain activities to inflict permanent and irreversible harm to the environment.

Recent legislation addressing environmental problems is designed to incorporate the external costs to the environment and to the public interest of certain activities into the decision-making process. This legislation has been in two categories: (1) Certain legislation has established procedures and institutions for the positive preservation of the environment to enable the concepts of conservation and development to be tied together by comprehensive planning. (2) Other laws have been concerned with the promulgation of standards. This type of legislation has created "standard-setting" responsibilities for certain agencies and charged other agencies with enforcement responsibilities to function as a control mechanism for the preservation of the environment.

B. Current Environmental Legislation Related to Transportation Systems

Recent federal environmental legislation acts as a constraint upon the construction of new transportation projects to insure the consideration of the adverse environmental effects of the proposal.

The National Environmental Policy Act (1969)

[9]

The purpose of the National Environmental Policy Act (NEPA) is to elevate environmental considerations to equal importance with technological and economic factors in the prior processes of decision-making. The requirements of the act are applicable to every project proposal sponsored by a federal agency which significantly affects the quality of the human environment. The provisions of §102 emphasize that sponsoring federal agencies are to (1) utilize an interdisciplinary approach, (2) include in every recommendation or proposal for legislation a detailed statement of the environmental impact of the proposed action, and (3) develop and describe appropriate alternatives to recommended courses of action. Specifically, §102(2)(c) requires each agency to submit a detailed "environmental impact statement" which must include the following:

(1) the environmental impact of the proposed action

(2) any adverse environmental effects

which cannot be avoided should the proposal be implemented

(3) alternatives to the proposed action (including not building)

(4) the relationship between local short-term uses of man's environment and the maintenance and enhancement of long-term productivity

(5) any irreversible and irretrievable commitments of resources

Title II of NEPA creates a Council on Environmental Quality in the Executive Office of the President which is composed of three members appointed by the President to serve at his pleasure with the advice and consent of the Senate. The Council on Environmental Quality has prepared guidelines regarding the environmental impact statements to be submitted by federal agencies. The guidelines provide that (1) draft environmental statements are to be made available to the public and circulated to other interested federal agencies at least ninety days prior to administrative action, and (2) final environmental statements with agency comments must be made public at least thirty days prior to administrative action.

It should be emphasized that the function of §102 is to serve as an input device to assist the decision-maker rather than as a mere procedural requirement to be complied with in order to receive federal funds. §102(c)(iii) of NEPA requires that a federal agency submit an "environmental impact statement" which includes alternatives to the proposed action. Perhaps the proper objective of NEPA's analysis of alternatives, in the context of current transportation problems and comprehensive multimodal planning, is to affirmatively explore "the suitability of other modes of transportation to accommodate similar objectives of the project proposal with less environmental disruption" [10, p. 24].

Within the Department of Transportation, the Office of the Assistant Secretary for Environment and Urban Systems is charged with the responsibility of implementing NEPA and to review in accordance with the provisions of §102(2)(c). The Office of Environmental Quality exists under the Assistant Secretary for Environment and Urban Systems and functions to actually review the NEPA environmental impact statements for transportation proposals for the entire country. The staff appears to be undermanned. Approximately seven reviewing members must identify and expose "straw" alternative proposals which have been offered by sponsoring agencies merely to comply with the procedures. In fact, the Office of Environmental Quality may have to rely heavily on conservation groups such as the Sierra Club for expertise and environmental input data to properly evaluate the NEPA impact statement. Clearly the Office of Environmental Quality is overburdened by its duty to review the NEPA §102(2)(c) environmental impact statements. Two proposals have appeared to deal with this necessary decentralization of environmental review required by NEPA. One proposal suggests that DOT develop within its separate administrations the interdisciplinary environmental skills at the field representation level. An alternative solution is to establish regional offices of the Office of Environmental Quality to coordinate with the mode-oriented administrations of DOT [10, p. 36].

A detailed discussion of legislation and administrative protection for the environment relating to highway location and airport location can be found in Appendix D.

4.2.4 Transportation—A Causal Parameter in Land Use

A case in linear land development (ribbon development) is adequately illustrated by the Baltimore-Washington Highway, U.S. Route 1 [11]. When it was first constructed, it had a speed along most of its 30-mile length of 50-55 miles per hour. By 1943 this highway was lined with development. There was an entrance and exit to a commercial or residential structure every 125 feet. Since most of these caused traffic to enter or leave at right angles and at comparatively low speed, the road was hazardous and speed was forced down to 35 miles per hour in most sections. In addition, billboard distraction was high. A count indicated that 2,450 billboards or commercial signs cluttered the sides of the roadway.

The above case is by no means an isolated one. "The Boston Post Road from the New York state line to New Haven, Connecticut, boasted 2,900 buildings with direct access to the highway. Gasoline service stations averaged one every 895 feet, and eating places competed at the rate of one every 1,825 feet" [11].

The pattern of growth is clear:

unlimited access transportation modes imply unlimited access

oriented growth in the absence of any controlling forces.

Refer to Figure 4.1 for a stylized example view. The converse is almost true also. At the interchanges of limited access roads there has resulted clumped development. However for two reasons, the quality of this development has been higher and the quantity lower. First, space is at a premium. The traveller will only go short distances "out of his way" to obtain goods and services. Second, the clumping of business puts competition close enough for comparison. Only the best can survive and to be best requires capital and planning. However, as any traveller can attest from personal experiences, limited access is not the entire answer either. The answer is growth and land use planning—but that is the subject for the next section.

4.3 Land Use: Tool or Product Of Transportation Design

Even to the most casual observer, mobility and its vehicle, transportation, is becoming more difficult to obtain in the full measure needed to satisfy the appetites of an urbanizing population. The benefits usually obtained by increased population densities are far outweighed by the complexities of a densely populated metropolitan area. The more people concentrated in a given land area the more people are affected by any change whether in land use, transit service, or something as superficial as street renumbering. These pressures for change and improvement, as strong as they are, are outweighed (sometimes decisively) by the pressures of status quo, special interest, and ignorance. Yet, this ignorance is not that of the illiterate or the undereducated; it is the ignorance that comes from incomplete scientific information and an inconclusive understanding of the complex nature of the problem.

We have problems generated by that greatest of all American panacea: growth. The urban diffusion of people, the pockets of ultra-high concentration, and the continual change in the land use patterns seem to be keeping us busy just keeping up with the build/decay cycle. Suburban living is often made possible by easy freeway access which provides transportation to the city. The phenomenon of the ever-expanding metropolitan area is a result of road placement—as well as a result of zoning laxities and developer imagination.

Recall our discussion of the transportation/demand spiral. The more transportation we seem to provide to meet a given demand, the higher the demand rises. We reach the conclusion that what is necessary is the coordinated use of land, urban design, and transportation. This section will explore the role of urban land use as a long range tool to enable transportation to provide for the necessary quality of life. The discussion will include zoning, the interaction between land use and transportation, and new city designs.

4.3.1 Zoning

The purpose of zoning is to separate a municipality into districts for the most appropriate use of land as defined by general rules according to a comprehensive plan. The historical basis of zoning lies in nuisance laws. To support an action for a private nuisance it is necessary to demonstrate the following: (1) actions of landowner evidencing a clearly unreasonable use and (2) the unreasonable actions resulting in damage to the legally recognized property rights of another. A consideration of the surrounding environment is necessary to determine whether or not the use is unreasonable. A public nuisance is defined as one which affects the public at large. A private individual is required to show "special damage" in order to obtain damages from a public nuisance.

A municipality has no inherent power to zone. A prerequisite to a municipal zoning ordinance is the existence of special enabling legislation passed by the state legislature, or specific state constitutional authorization. Any zoning ordinance is thus confined to the limitations fixed in the enabling statute.

A. The Constitutionality of Zoning

The historical argument against the validity of zoning as unconstitutional averred a violation of the Fourteenth Amendment as a deprivation of liberty and property without due process of law and that zoning denies equal protection of the laws. In the landmark case of *Village of Euclid* vs *Ambler Realty Company* (1926), [12] the Supreme Court significantly upheld the constitutionality of a cumulative type zoning ordinance (that is, the uses enumerated in less restrictive subsequent classes of land include those enumerated in the preceding classes). The separation of a municipality into separate land use districts was upheld as an extension of the police power of the state and justified as sub-

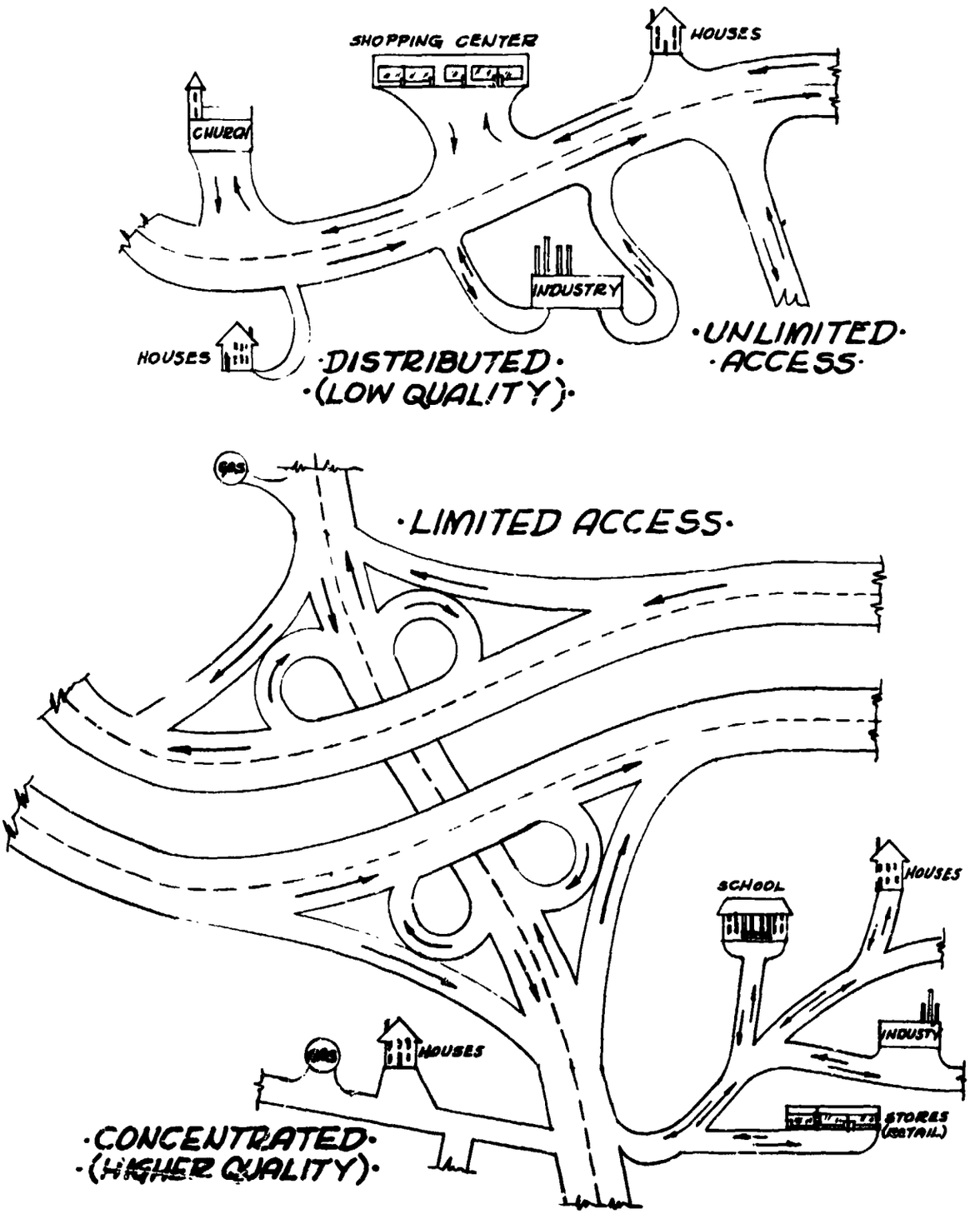


FIGURE 4.1
STYLIZED VIEW OF DISTRIBUTED VERSUS LIMITED ACCESS HIGHWAY GROWTH

stantially related to regulation for public health, safety, and general welfare. A test for land use classification and allowing certain uses in zoning districts is based upon the compatibility of the use with the area.

Several basic principles can be recognized in relation to the constitutionality of zoning ordinances. For example, it is unconstitutional to have an ambiguous ordinance not specifying what is permitted and prohibited. A zoning ordinance providing regulation for the minimum size of dwellings is valid as being reasonably related to general welfare. However, when the underlying scheme of zoning has an exclusionary purpose to regulate population it may be unconstitutional [13]. For a zoning regulation which effectively limits population density to be valid, there must be a reasonable relation to problems of public health and general welfare, such as sewage problems. Furthermore, a zoning regulation which prohibits **any** reasonable use of the land is unconstitutional because the owner of land is entitled to a reasonable return on his investment. In 1954, the Supreme Court in *Berman* vs *Parker* [14] permitted zoning on the basis of aesthetic considerations alone. Beauty was determined to be a proper community objective attainable through the use of the police power in protecting public safety and general welfare. The green belt (or open space) concept of zoning is to provide an appreciable rural zone around the urban area, and inside the green belt approval is not to be given for the construction of new buildings. However, if all land owned by a particular landowner is zoned green belt, it may be an unreasonable and unconstitutional taking if the landowner is unable to get a fair return on his investment. So, as long as there exists a reasonable basis for zoning to protect the public health, safety, and general welfare, there is no constitutional denial of equal protection or taking without due process. A taking of property must be distinguished from a permitted regulation for general welfare in accord with a city plan.

B. Departures from Zoning

To sustain an **amendment** to a zoning ordinance once a comprehensive plan for development has been drawn up, it must be shown either: (1) that there was a mistake in the original zoning, or (2) that there has been a substantial change in conditions of the permitted use of surrounding land. Zoning cannot act retroactively, and thus **non-conforming uses** exist as to structures on the land (**not** in the land itself). The basis of the doctrine of non-conforming uses is the investment in the property (buildings). A non-conforming use must be existing at the time of adoption of the ordinance and is permitted to be continued, but not extended. If an ordinance acts unfairly with regard to specific property, a **variance** may be sought from the administrative board of zoning appeals based on the substantial hardship incurred because of the nature of the land in relation to the zoning law. A variance allows a slight deviation from the zoning ordinance because of the uniqueness of the land itself.

C. Subdivision Control

A subdivision ordinance regulates **lot sizes** and does **not** include the doctrine of non-conforming use. By subdivision control, the government within its police power can require the developer to dedicate a portion of his land for public use and the general welfare. Schools and parks are considered necessary for public health and the general welfare.

D. Government Use of Eminent Domain to Control Land Use

Originally, the government's use of the power of eminent domain was restricted to a taking for "public use" (which denoted that title to the land was to be in the government). However, the initial concept was altered by Urban Redevelopment Plans to allow a taking for a "public purpose" (which allowed the government to deed the land back to a private developer). The government can thus condemn with just compensation and take slum areas by eminent domain. The "public purpose" justification lies in dealing with the public health problem. The limitation of "public purpose" to slum clearance has now been expanded so that "public purpose" can also be economic promotion according to the New York World Trade Center case [15]. It must be recognized that zoning cannot be used as a substitute for eminent domain to defeat the requirement of a taking with just compensation. The regulation by police power which incurs **no** compensation must be distinguished from the taking of property by eminent domain because it is useful to the public—and the accompanying right to just compensation.

E. Conclusion

Until now, zoning legislation has been much too concerned with the preservation of

land values rather than promoting affirmative land development plans. However, in implementing future land development policies, presently allowable zoning legislation may encounter constitutional challenges as either (1) taking without due process and not allowing a reasonable return on the investment to the landowner, or (2) as amounting to a taking without just compensation.

4.3.2 The Interaction Between Land Use and Transportation

An analysis of the environmental impact of transportation must necessarily consider the interaction between land use and transportation. Transportation systems have traditionally been planned in response to travel demands created by the development of an area. As a result, the reciprocal process by which land use affects travel and by which transportation facilities affect land use has remained largely unrecognized. However, earlier land development decisions act as an input in generating the travel demands to be served by a transportation system. Therefore, an understanding of the effect of land development decisions in the context of transportation policy is necessary.

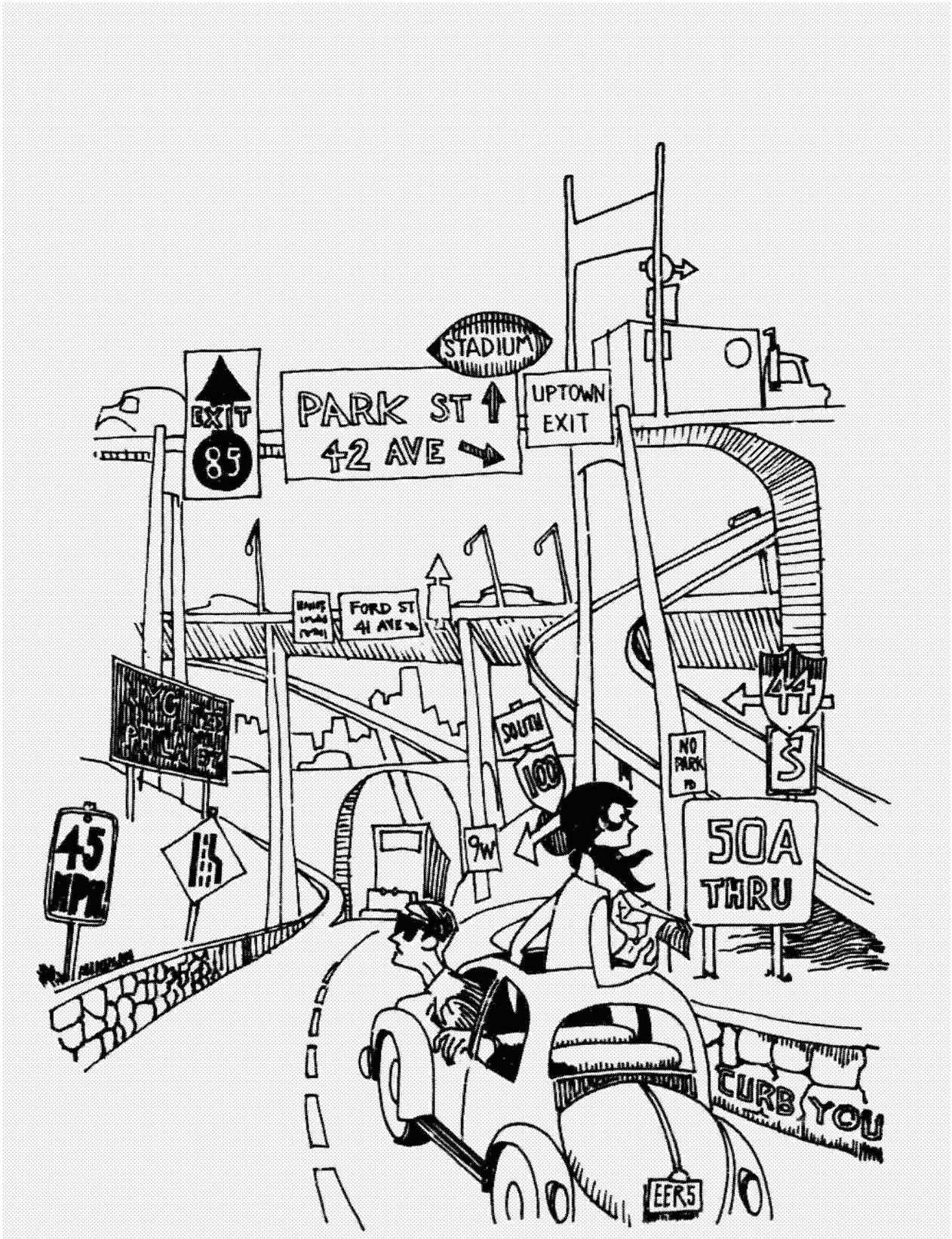
The impact of transportation upon land use is both diverse and complicated. In an attempt to describe the interrelationship between land use and transportation, two hypotheses regarding the role of transportation have been advanced [16, p. 396]. The initial theory considers that transportation responds to land use development and therefore transportation planning should serve future land development. The contrasting view is that transportation affects patterns of development and land use activities, and thus transportation should be designed to achieve socially meritorious objectives. The Bay Area Land Use analysis proposes a process by which transportation increases the accessibility of a geographical location, the improved access raises land values, and ultimately land use patterns are affected. Access is defined as the " . . . effective nearness to all other activities or those of interest . . . " [16, p. 398]. Specific examples of varied land use impacts created by transportation can be identified. For instance, the transportation-access-land use process suggests that as the efficiency of transportation increases and activities disperse, distant locations will be more accessible, and the value of central locations will decline. However, an impact of rapid rail transit facilities may be to locate new high-use offices in the central business district. The attraction of increased employment opportunities may reciprocally result in an influx of commuter automobile traffic into the city. Thus, rapid rail transit may not have the effect of decreasing the number of automobile trips.

Since no regional zoning power is available, several approaches exist to implement a containment policy to restrain land development that results in adverse transportation impacts. It is suggested that perhaps environmental regulations and constraints should control land development to facilitate comprehensive planning of land use and transportation. The preservation of agricultural land and public parklands can act as a broad environmental constraint on land use. Regional control over utilities could be effectively utilized to restrict land development. It is also evident that land tax reform is necessary so that growth, merely to provide a tax base, is not an impetus in community planning and development.

A. The Social Effects of Transportation Systems

Transportation systems also significantly affect social patterns in addition to land use development. In the past, transportation systems have functioned to improve geographic accessibility between two locations, and therefore promote economic development. The developmental role was limited to the transportation of goods and labor. However, now transportation must recognize a new function—to improve the accessibility of people to each other. Transportation must serve both as a medium of communication and to promote human development.

The present lack of a defined national transportation policy and the concurrent emphasis upon roadway construction have resulted in ominous social implications. The effects of the automobile-driver-highway system have worked to the disadvantage of the poor and urban carless. The proliferation of highways has additionally contributed to the decay of urban transit systems, which are relied upon by the non-majority groups. The cycle of transit decay is characterized by (1) roadway construction which encourages the use of private automobiles; (2) transit fares are then raised to compensate for fewer riders; (3) the higher fares contribute to increased use of private automobiles; (4) ser-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vices are curtailed; (5) fares are raised still higher and patronage declines again [8, §3.04 [5], p. 3-362]. The culmination of the adverse effects of an unbalanced investment in highways is the urban blight problem of our central cities.

The dispersed pattern of trip origins and destinations associated with suburban residences and recently suburbanized industry is incompatible with the high-density operational requirements of transit systems. The resulting social problem is that jobs in suburban industries are inaccessible to the carless population living in the central city. The solution to the problem lies in redirecting transportation policy to serve specific population groups. The alternative of moving to a suburban residence is an unlikely prospect for the urban poor. Therefore, transportation access from the inner city to the outer metropolitan areas—outbound transit commuter service—must be improved to provide mobility for the urban poor.

There are severe problems existing in current transportation systems requiring innovative reassessment of our transportation policies and priorities. Highway congestion, safety problems causing fatalities on the highways, citizen resistance to continued construction of highways through urban areas and the location of airports the pollution of the atmosphere, decaying public transit and the immobility of the non-driver, and insufficient coordination among the various modes of transportation are all problems of national transportation. Until now, systems design in transportation planning has been dominated by a narrow transportation concept of efficiency which did not take into account the effects of changes in transportation upon the broader urban and societal systems. For instance, present cost-benefit tests of alternative transportation system designs measure only direct user benefits and capital costs. Both quantitive values are internal to the system. But once it is recognized that the dominant consequences of a transportation system are external and it is conceded that transportation systems must satisfy social purposes, the optimum systems design must reflect these contributions to broad nontransportation purposes [8; §3.04 [5], p. 3-358].

4.3.3 New City Design

"If transportation is not intrinsically good, why promote more of it?" In the final anaylsis, transportation planning can never be divorced from city planning. The transportation planner cannot ignore the effect his plans will have in the city and its surrounding environs. The goal of this integrated form of design is to preserve mobility yet decrease need for physical transport of people. When a new city is being planned, the opportunity to integrate city planning and transportation is a double benefit. It has been estimated that the equivalent of a hundred new cities, each with a population of a million people, will be necessary to accommodate the projected increase in population over the next fifty years in this country. It seems obvious that our existing cities cannot easily place these numbers of people without significant overcrowding. What is needed are a number of "new cities" carefully planned to handle millions of people in a manner consistent with the physical, psychological, and social needs of the population [17].

Ideally, such a new city should be designed to **minimize** the need for transportation. The working members of the family should not have to travel on long, exhausting commuter trips each day; the children should be able to walk to school; shopping and recreation should not be far from the residential areas. The essential services of medical care, grocery stores, churches, schools, etc., all should be located within the neighborhood in such a way so that all the residents have easy access to them.

At the same time, care must be taken to ensure that transportation planning does not interfere with other basic human needs and desires. Locating workers' houses near their work should not result in increased noise, air, or visual pollution for the residents. Making shopping, schools, and services accessible should not interfere with people's desires for space, tranquility, and the benefits of nature. Above all, transportation should serve the needs of man—not the reverse.

How are these grandiose goals to be achieved? One promising approach is clustering [2,18]. Clusters of neighborhoods are built around a community core; the communities are built around a town core to form a town; towns are built around a city core to form cities, and finally, cities are built around a "metro-core" to form a metropolis. Such a structure is analogous to a planetary system with a number of planets revolving around a sun. Each planet has satellites, and each satellite has still smaller bodies circling it. Figure 4.2 illustrates the concept.

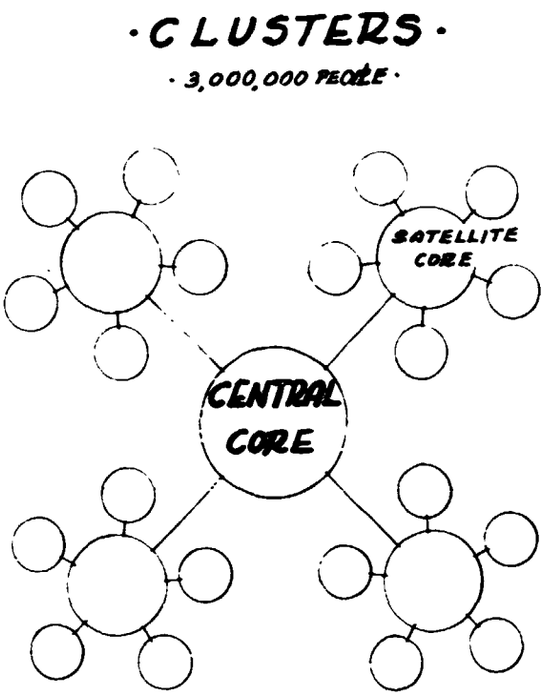


FIGURE 4.2
ILLUSTRATION OF THE CLUSTER CONCEPT OF NEW CITY DESIGN

The premise behind such clusters is equal and easy accessibility for residents to a nearby core. When communities of a regulated size (area and population) are spaced equally around a core containing schools, churches, shopping, and other services, transportation needs are reduced, and transportation requirements are readily identifiable due to the planned nature of the urban design.

Victor Gruen [2] has proposed that "green belts" be maintained between all of the centers. The space between centers varies. The area between the neighborhood and the community center would be small, while the area between the city center and the metro-core would be quite large. Within these green belts would be parks, orchards, recreational facilities, forest, lakes, and the like. Every center would have essential services, with the community center having less diverse offerings than the town, which would have less than the city, which would have less than the metro core. But even the community would have elementary schools, food stores, recreation facilities, and some places of employment (mostly service occupations). The majority of the manufacturing plants would be concentrated in industrial parks located outside the cities but easily accessible via public transportation. Most cultural facilities (museums, concert halls, stadiums) would be located in the city cores and/or the metro-core.

What about transportation? There are a number of possibilities. In one scheme [2], a high-speed rail (or TACV) system connects all cities with the metro-core and with the industrial parks. Inner-city transit (bus or rail) would connect each town center with its city core. Minibuses could connect each neighborhood with its town center.

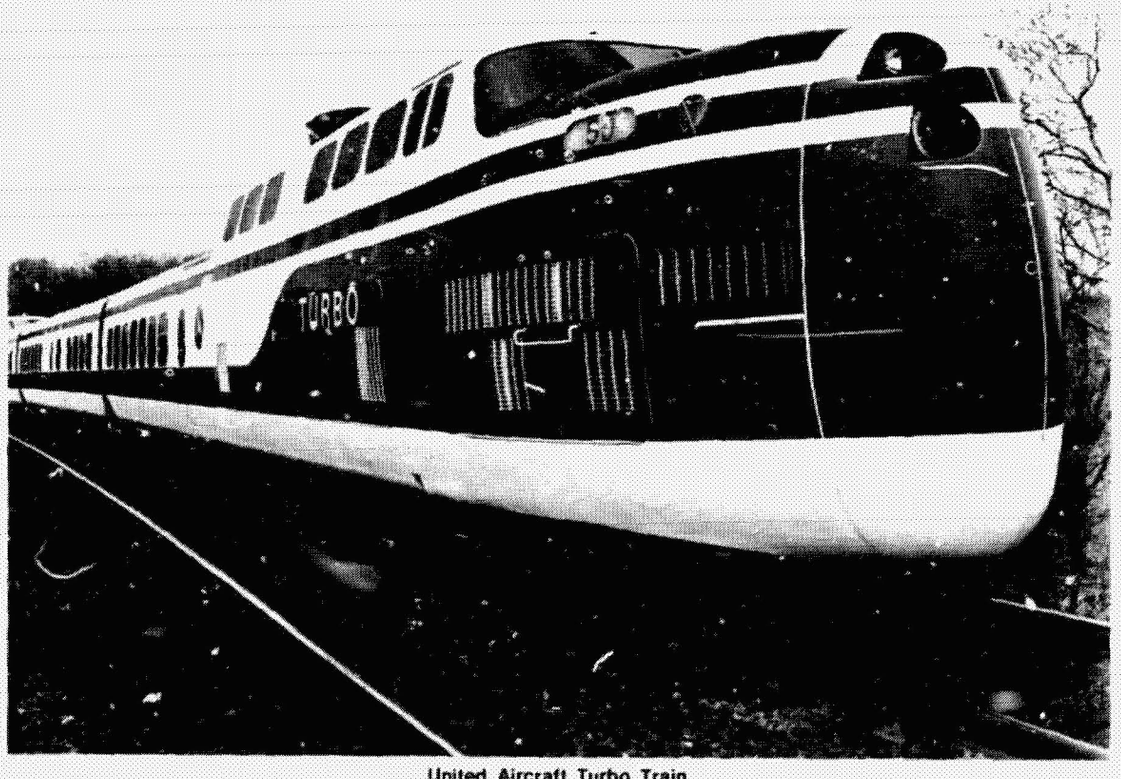
Automobile use would be restricted simply by not building major highways within the satellite cities or from city to metro-core. Freeways surrounding the cities will interconnect with each other, and with a national highway system leading out of the whole city at the fringes. Private cars would be utilized for out-of-town travel, for travel among neighborhoods and communities and for travel into parts of the nature reserves. However, comfortable mass transportation will offer greater speed and convenience (at reasonable costs) for trips from town centers

to city centers, city centers to the metro-core and to the industrial parks than the automobile.

Finally, the city of the future should emphasize the oldest transportation mode of all—walking. Neighborhoods, communities, towns, cities, and metro-cores should be designed to make the pedestrian's walk attractive to his eyes, his ears, his nose, and his lungs. Colonnades, arcades, and overhands for sun and rain protection, rest benches, attractive architecture, nature displays, and, in the cities and towns, attractive store windows, all without a heavy concentration of automobiles, will combine to make walking enjoyable. Many areas will be designated pedestrian malls with no provision for automobile traffic. One fringe benefit of such a scheme will be healthier, hardier people! Mini-bus transportation (such as at the New York World's Fair) will be provided for the handicapped and the aged.

Two other example forms in addition to the clusters are zone cities and conglomerate cities. The zone concept is similar to many European designs. Figure 4.3 illustrates the concept. Notice that the population center is located in the geometric center of the city. The advantages of this location are two-fold. First, the mean travel distance to any location in the service zone or the heavy industrial zones is *minimal*. Second, *people are not* required to travel wholly through populated zones in order to get to work, or to shop, or to obtain daily service needs.

The location of the service zone and heavy manufacturing zone have been carefully selected as well. The service zone is in close proximity to both the population center and the heavy industrial zone. This also places the burden of through traffic on this zone. Hence, noise and other undesirable side effects of much of transportation are kept away from urban living areas. The location of



United Aircraft Turbo Train

the heavy industrial areas on the outer ring allows for open access to heavy modes of transportation rail, barge, etc. In addition, that almost inevitable by-product of pollution that accompanies any large production effort is located away from population areas and is distributed to avoid highly concentrated point locations. Thus, by employing the zone concept of urban design, the transportation requirement of an urban area can be kept radial in nature. This form of transportation is well-suited to rail or guideway forms of implementation. All of the advantages of urban planning are realized in this form with a minimum of regimental control.

In the extreme, clustering takes the form of an entire community in a single building: the conglomerate. This form is illustrated in Figure 4.4 Here we utilize the 10-fold increase in mobility vertically over horizontal movement. That is, every floor (10 feet of vertical or elevator movement) we have open to us an entire unit of area. If all that area were placed side-by-side on the same plane, it would take 100 feet of (horizontal or walking) movement to open up an entirely new area. Thus, it would appear to be ten times more efficient to move vertically than horizontally.

The preceding is, of course, the bare skeleton of some possible plans. Undoubtedly, superior designs which better integrate transportation and city planning may be created. The purpose of presenting these plans here has been to emphasize the importance of overall city planning in the solution of transportation problems. Indeed, the relationship is reciprocal: transportation planning can be invaluable in contributing to prosperity and the quality of life in the city.

4.3.4 Transition: An Incremental Approach to New Design

New ideals, of course, do not answer

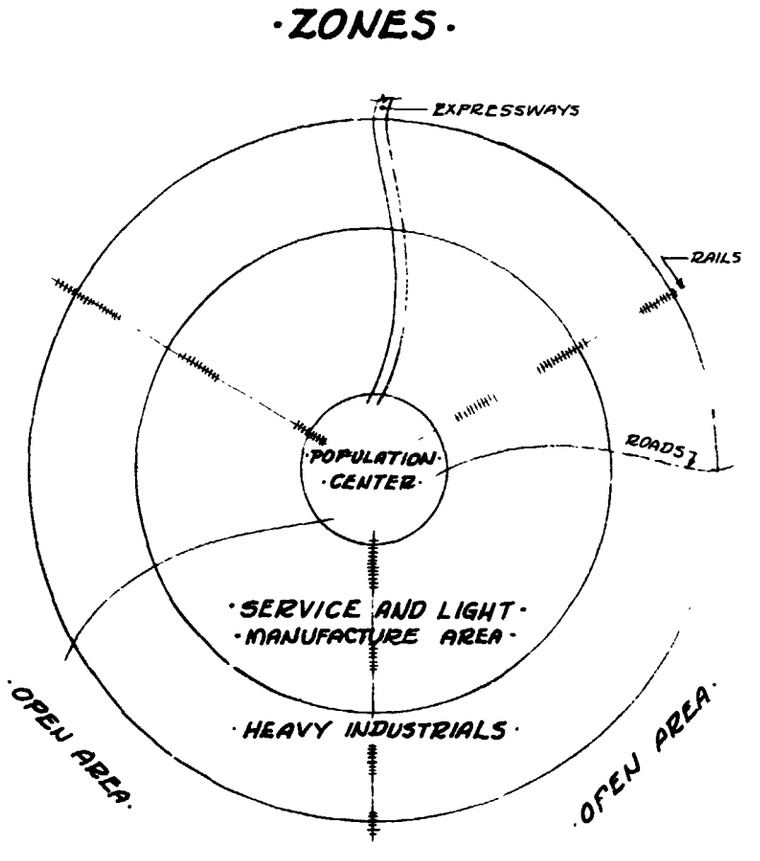


FIGURE 4.3
ILLUSTRATION OF THE ZONE CONCEPT OF NEW CITY DESIGN

·CONGLOMERATES·

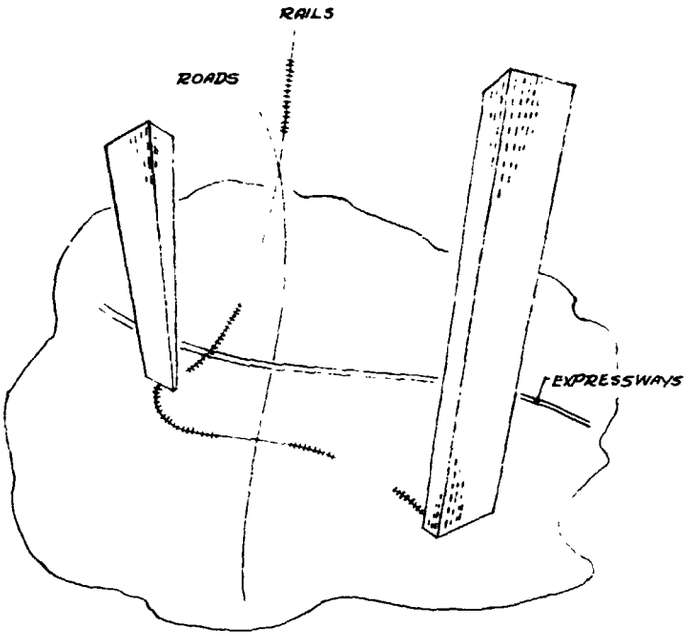


FIGURE 4.4
ILLUSTRATION OF THE CONGLOMERATE (CITY IN A BUILDING) CONCEPT OF NEW CITY DESIGN

today's problems, given the fact that we exist with our cities and communities already built and in need of remedy. We have neither the resources nor the time to wait to build completely anew. We need a plan.

A plan is needed which will allow an incremental approach to new design. Such a plan is not within our limited time to develop. It is a long process requiring perhaps all the skill and talent we can muster as a country. Some fundamentals are visible to us at this time. They are important aspects which should do much to help begin the serious work ahead.

First, an adequate transportation system cannot be built using methods whose failure is apparent today: e.g., a congested two-lane road does not "logically" suggest a four-lane, divided highway.

Second, improvement cannot come by subtraction alone: i.e., creating downtown traffic-free malls by banning autos does not solve the problem. An addition is required in order to add beauty and improve environmental qualities and adding other means of mobility such as walking, short-trip transit, and package delivery.

Third, although the new designs have much to offer, we have much invested in the old designs: thus, our action plan should concentrate on intermixing the two. However, the new transportation system should exploit existing facilities in new ways rather than allowing old facilities to dictate new systems.

Fourth, transportation itself is a powerful force in growth. It is capable of determining the character of large areas of land and influencing life styles. Mobility (and modes of transportation) between **old** and **new** and within **new** must fit the requirements of the **new**. Note that this concept is exactly the opposite to what is now done. Now we wait for demand before service is supplied.

Finally, the conversion should be done in sectors for visibility, and convenience, and to attract stable capital.

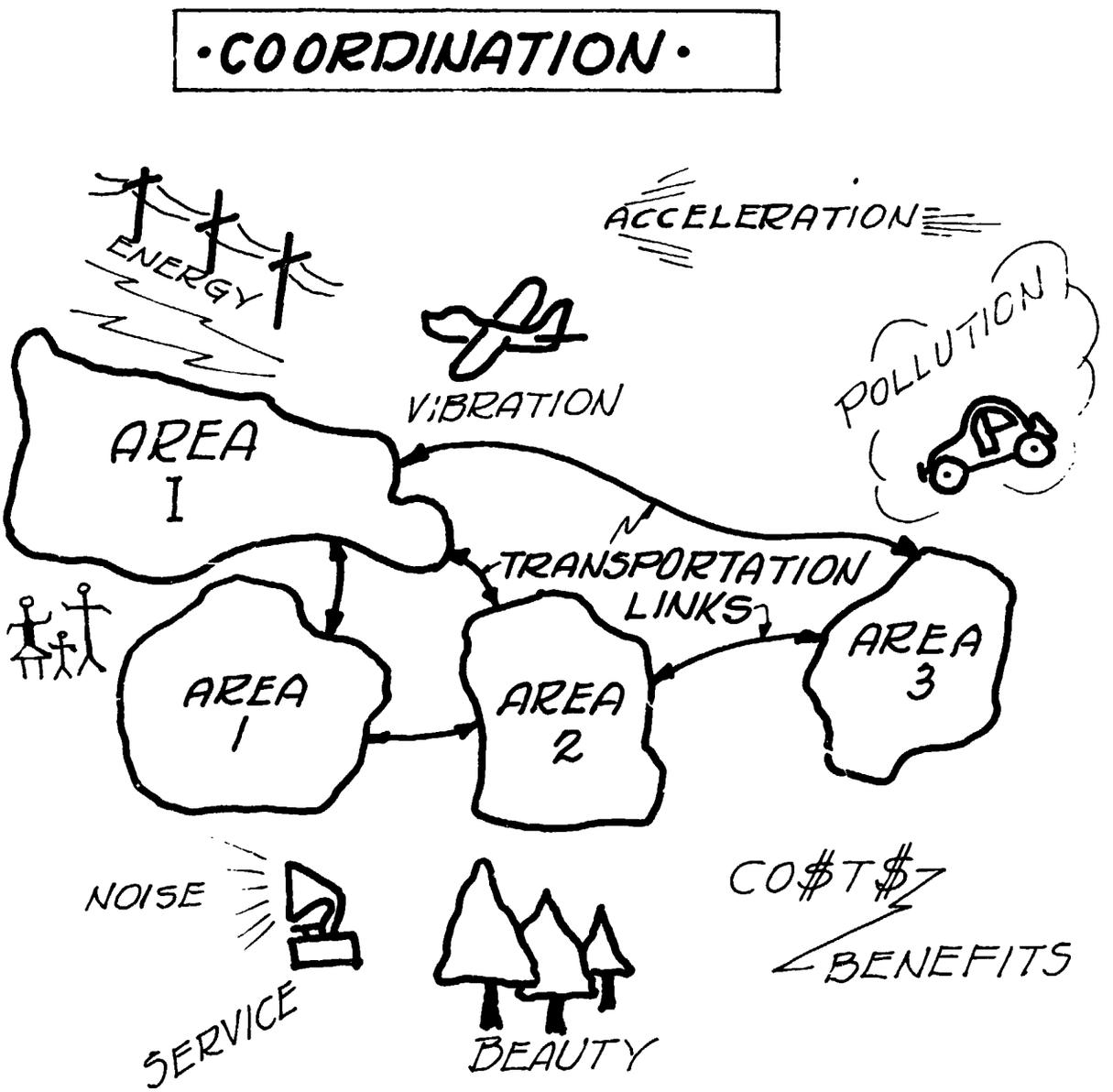


FIGURE 4.5
REQUIREMENTS FOR SYSTEMS DESIGN

Summary

We have explored some aspects of the environmental relationship of mobility as illustrated by Figure 4.5. A great deal needs to be coordinated. This coordination will allow a unified approach to the integration of urban design and the transportation it requires into the life styles that people wish to develop. An important concept has been presented. That concept in effect recognized that transportation plays an important role in shaping the spatial nature of urban areas. If we are to exploit that force, new designs must first incorporate the new forms of transportation which suit the new ideas before other construction has been substantially begun. An important aspect is that adequate transportation systems can shape growth through natural factors and pressures without need for exhaustive, explicit, overt controls.

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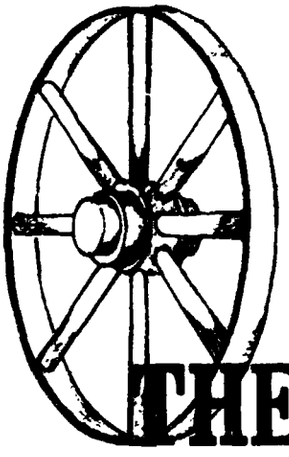

THE CIRCULATORY SYSTEM and Its CONSTRICTIONS

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The Circulatory System And Its Constrictions

The main thesis of this chapter is that transportation is but one part of a larger system, the circulatory system, which provides the needs as well as the means for mobility. In addition to describing the structure and operations of this system, the chapter also lists specific constrictions or bottlenecks in the system arteries and interfaces which have retarded improvements in mobility and quality of life.

The larger system to be discussed is circulatory in nature, i.e., a change in any part of the system will propagate around the system and ultimately return as an effect on the original part. The realization of this fact and actions based on this realization are the keys to successful transportation system design. The word successful implies another key element of transportation, the fact that the successfulness of any transportation system is dependent on the acceptability of the system by people—both users and nonusers. This acceptance by people enters at all points in the system and introduces human factors as a major element in transportation.

As a means of considering the transportation scene in an organized manner, let us look at engineering systems and their design. Although the system approach is not the panacea which will cure all transportation ills, it does provide a vehicle which may be used to move closer to the solution of the problems in transportation.

A. Structure of the Circulatory System

1. General Theory of System Design

Engineering design has been defined in different ways by many authors. For example, Asimow [1, p. 1] states that "Engineering design is a purposeful activity directed toward the goal of fulfilling human needs, particularly those which can be met by the technological factors of our culture." Woodson [2, p. 3] is more specific in stating that engineering design is "an iterative decision-making activity to produce the plans by which resources are converted, preferably optimally, into systems or devices to meet human needs." Note that a key aspect of both definitions is the fulfillment of a human need.

The philosophy of engineering design is that it must not only lead to action but must also embody a methodology for providing this action. To implement this philosophy requires an approach which contains essentially four elements. The **first** element in systems design is the overt formulation of specific goals, i.e., a needs analysis. These goals must be formulated in an environment where the interactions of the various elements of the system are recognized. The **second** element in systems design is the development of a specific plan, one which includes a time schedule for milestone accomplishments. The **third** element is the establishment of an organization which has responsibility for accomplishment of the tasks outlined in the plan. This organization must be effectively structured from an information transmittal standpoint as well as from an authority standpoint as portrayed in Figure 5.1. An essential element of the program organization is that it be circulatory or iterative in nature. This implies that feedback loops must be overtly planned to guarantee adequate analysis of impacts and effects of any proposed concepts. This aspect of the organization is shown graphically in Figure 5.2.

The **fourth** and final element of systems design is the provision of appropriate tools for accomplishing the tasks at hand. One very important tool for today's systems designer is the combination of modeling skills and simulation machines which make possible the testing of consequences of alternate solution ideas.

2. Transportation System Design

A transportation system can be considered as a device which satisfies a human need. The need in this case is the movement of people from one location to another, and the system is all of the means or modes for transporting the passengers together with the associated regulating agencies. If the transportation picture is considered from this point of view, i.e., as a means of satisfying a human need; then it fits into the framework of what is commonly called an engineering system.

The application of systems design concepts has become an accepted part of any transportation planning effort. The reason for this acceptance is the complexity of the problem and the usefulness of applying a systems approach to complex problems. For example, it has been said that, "one important aspect of these problems which becomes increasingly apparent is the anticipated absolute magnitude and complexity of future transportation. Associated with this is an increasing need for analysis of transportation

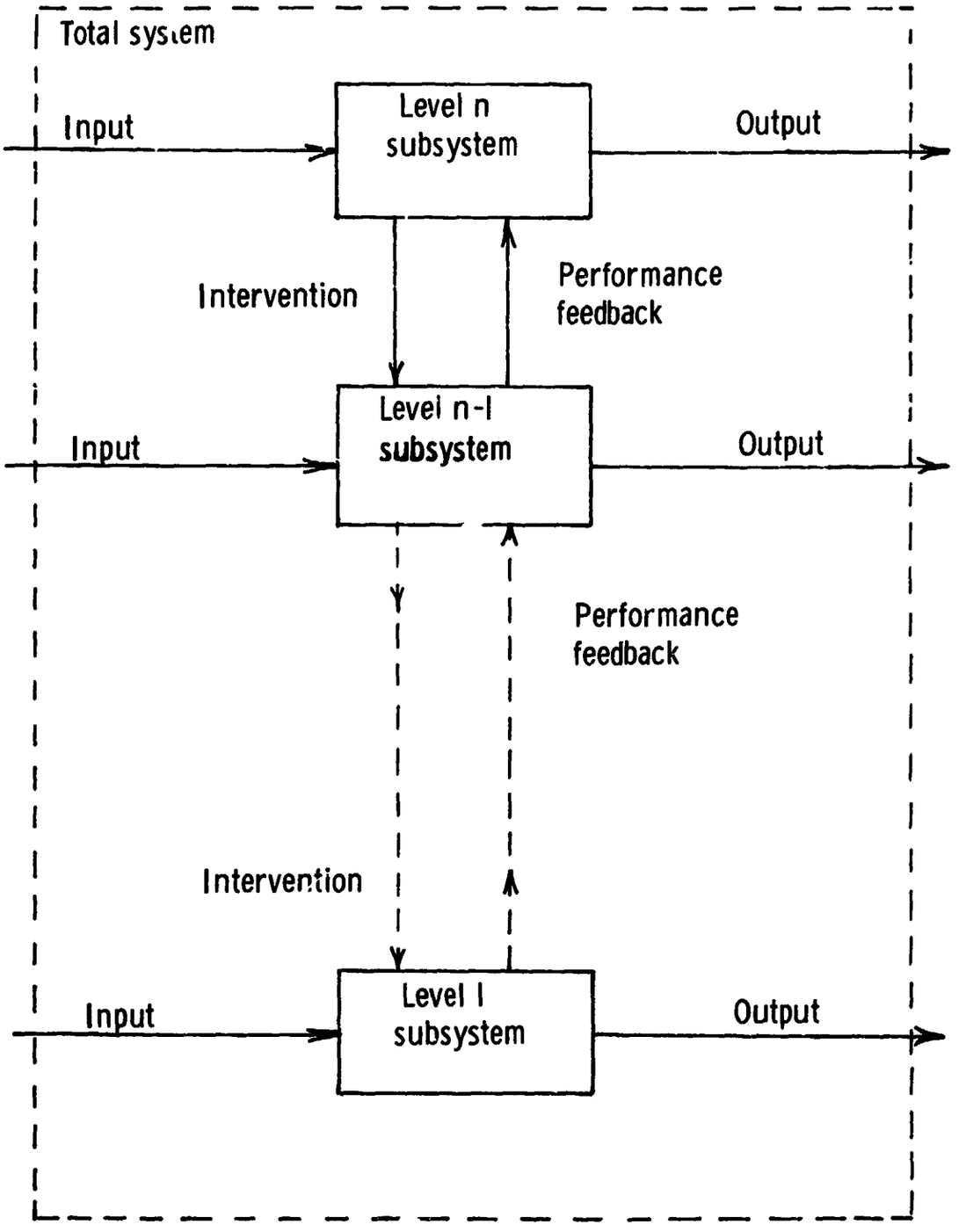
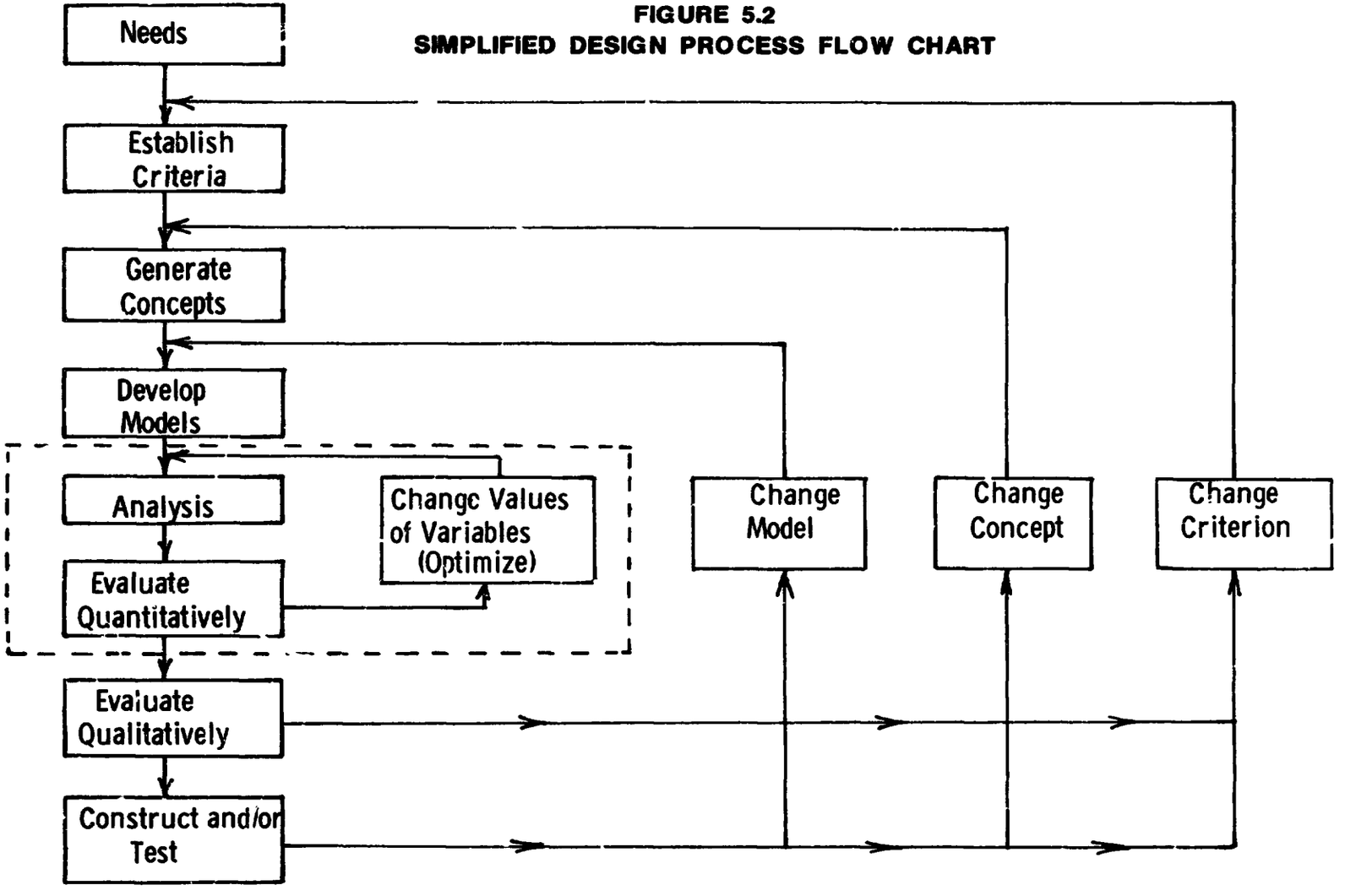


FIGURE 5.1
VERTICAL INTERACTION BETWEEN LEVELS OF A SYSTEMS HIERARCHY

Source: Mesarovic, M.D., Macko, D. and Takahara, Y. 1970.
Theory of Hierarchical, Multilevel, Systems. Academic Press, New York. p. 35.

FIGURE 5.2
SIMPLIFIED DESIGN PROCESS FLOW CHART



Source: Au, T. 1969. Heuristic Approach to Systems Design, *Journal of Engineering Education*, Vol. 59, No. 7, March 1969, pp. 861, 865.

from the viewpoint of looking at the system as a whole. The object of such an analysis is to insure a properly functioning, integrated system which will meet the needs of society in the most efficient way. The latter implies the need for conception and evaluation of various possible alternatives. Taken in total, these considerations point towards the necessity of a systems engineering type analysis." [Vol II, p. 169] The scheme for applying the systems approach is fairly common and is illustrated in Figures 5.3 and 5.4.

B. Stenosis in Transportation Arteries

Webster's New World Dictionary defines stenosis as a narrowing, or constriction, of a passage, opening, duct, in other words, a bottleneck. The systems approach to design, discussed earlier, is an idealization in that it does not account for "obstructions in the passageways of design." In reality, any system design process will include obstacles of many forms. A common feature of these obstructions is that they can be represented as constrictions of some path or artery in the planning or implementation process.

The purpose of this section is to emphasize the commonality of many of the problems discussed in previous chapters. By understanding the similarity of problems that appear to be very dissimilar, it is possible to use techniques and tools from one discipline to attack problems in other disciplines. This interdisciplinary consideration is at the heart of the systems approach to design.

The approach taken in this section is that a problem or "stenosis" falls in one of two categories: interface problems or feedback problems.

B.1 Interface Problems

An interface is the connecting link between two parts of a system. Interfaces can take many forms, ranging from the very tangible such as the tire tread interface between automobile and road to the intangible such as the planning interface between an old system and a new. A common characteristic of an interface is the dissimilarity of the two parts separated by the interface. Such points of division between dissimilar parts of a system are inherently problem areas, and the interfaces found in transportation systems are no different. Several interfaces and associated problems will be discussed in this section.

B.1.a The Interface Between Users and Transportation Systems

Perhaps the single most important interface on the transportation scene is the one between users and equipment. It is at this interface that most people develop their opinions and attitudes about transportation. The ideal interface would provide an environment which the user finds comfortable and safe, in which his sense of self-esteem is not jeopardized and in which he can participate in selected activities such as writing or reading—the chauffeur-driven limousine.

The major problem or bottleneck in

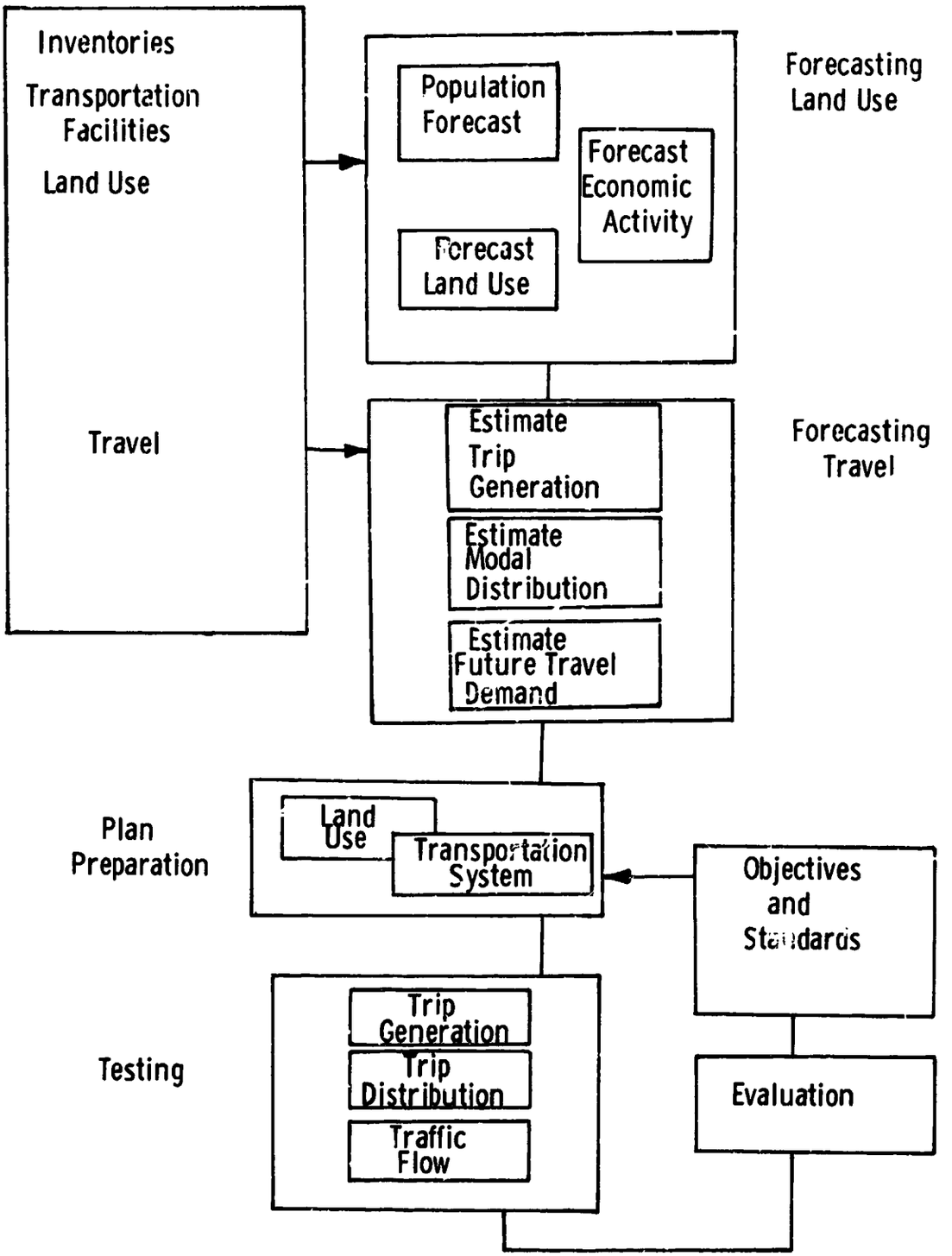


FIGURE 5.3
A FUNCTIONING TRANSPORTATION PLANNING PROCESS

Source: Chicago Area Transportation Study, 1960. Vol II, p. 2.

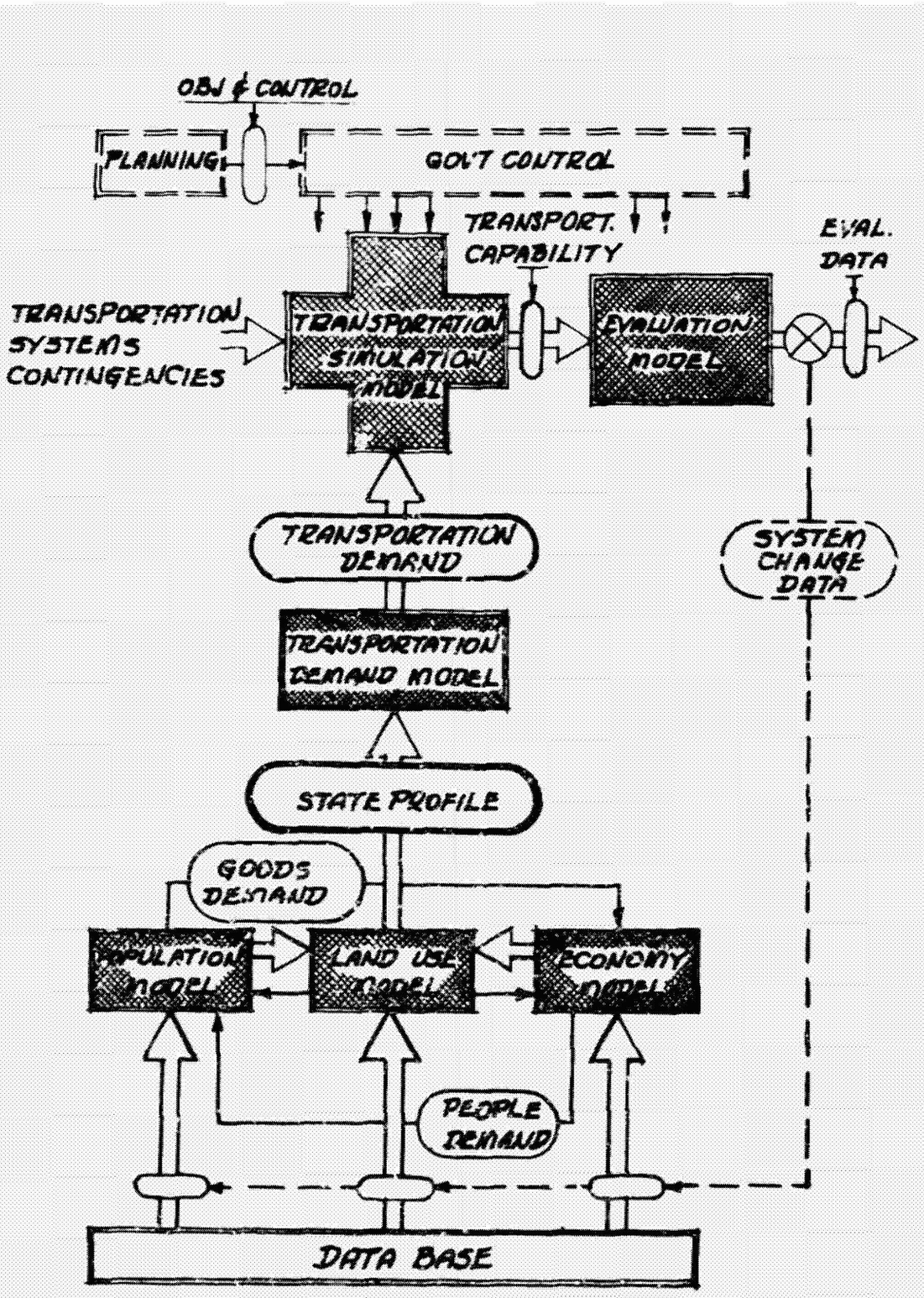


FIGURE 5.4
A PROPOSED TRANSPORTATION PLANNING PROCESS

Source: *California I. agrated Transportation Study*, 1965. North American Aviation, Inc., Los Angeles. Vol I, p. 25.

providing an ideal user-equipment interface is two-fold. The first aspect of the problem is the need for designers to realize the importance of a multitude of human factors in the user acceptance of this interface. The second aspect of the problem is the unavailability of data for use by the designer in making decisions on this interface.

The interface environment is characterized by factors which produce feelings and attitudes in the user. These factors are both physical and psychological. Only recently designers have begun to realize the importance of physical factors such as step height, head room, color, etc. While the understanding of physical factors has reached this level, the understanding of psychological factors is at a much lower level. The psychological factors such as crowding and fear most heavily affect feelings of self-esteem. The importance of this factor has not yet been appreciated.

The second aspect of the problem is the lack of data. There has been a tremendous amount of data collected on human factors, both physical and psychological, but it is of a specialized nature. Much of the data has been developed at various NASA and military facilities where the subject population for much of the data is composed of military personnel. There is also a strong emphasis on operator characteristics as opposed to rider characteristics. The type of data needed in the design of transportation systems would be based on civilian users. A civilian user population would be composed of not only physically fit males and females, but also handicapped people, people with packages and other types of disadvantaged people.

In summary, the human factors interface between user and transportation equipment is of prime importance in acceptability of a transportation system; however, this is an area where the need has not been realized in the past and the amount of pertinent data is minimal.

B.1.b The Organizational Interface

An interface area which tends to be a stenosis in the planning artery is the link between levels of government. A prime example of this link is the Council of Governments (COG). These units form an interface between the federal government and state or local government. A major problem area in the COG concept can be seen by comparing a typical COG with the systems structure given in Figure 5.1.

A COG interacts with both levels of government. Typically, a COG must develop a transportation plan for presentation to the federal government. However, in many instances, the COG does not have implementation authority. Thus, the COG provides the feedback of a plan from the local level to the federal level but does not have intervention power on the local level. Without this combination of power and responsibility, an interface tends to be ineffective, as many COG's are.

The transportation plan which a COG provides the federal government is itself a form of interface. In this case, it is an interface between the transportation needs of local society and programs for meeting these needs. In order to discharge this responsibility effectively, a COG should give consideration to all modes of transportation. In some cases, this multi-mode posture has been taken, but in many more, a single mode has dominated in the plans developed. The reason for this is very simple. Highway planners have been planning highways for a long time and there are many highway planners available for inclusion in COG organizations. On the other hand, the number of urban planners who are competent in multi-modal transportation are few. COG's must draw on available resources for staffing, and hence, there is a preponderance of highway planners on COG staffs. The result, of course, is a plan that emphasizes highways. The result of such single mode transportation planning is often a less than optimal satisfaction of societal needs.

B.1.c The Planning Interface

The process of developing new systems to replace antiquated systems is an important part of the total transportation scene. The planning part of this development can be considered as the interface between the old system and the new. The concept of an organized planning process has been accepted for some time, as discussed earlier in the chapter. The key to the effectiveness of these planning processes is the models that are used.

Of the various models used in the planning process, the transportation demand models are of key importance. This is one point in the planning process where human factors enter transportation planning. Without a good model of user needs and attitudes, the ultimate transportation plan can be very sterile with respect to human factors.

The current spectrum of so-called "Demand Models" are attempts at articulating the reasons why people travel. Unfortunately, some serious problems prohibit estimating this demand accurately. Transportation forecasting, in order to be relevant, must be for the long-term. Given the time and investment in any transportation facility, one must try to predict demand as accurately as possible. But, most available models, contrary to the intentions of the model builders, predict only for the short-term. Most models, thus far, have employed variables such as distance, time, prices, various nonmonetary costs, income, and population. Since some of these variables change slowly over short periods of time, they can be neglected as determinants of short-term changes in demand. But there are other problems which presently prohibit long-term demand.

The determinants of travel change little in a period of less than five years, but they may change drastically if one looks at a period of about ten years or more. Thus for short-term models, factors such as population and wealth, the supply and technical characteristics of other communication substitutes (e.g., telephone service), the role of travel as an input to industry, especially as markets expand and shift geographically, and the technical characteristics of transportation facilities can be assumed constant; for the long term they are dynamic. [4, p. 24]

A serious problem with this type of model is that certain determinants of modal choice cannot be extended to estimate demands of nonexistent modes. This inflexibility is due to the fact that new modes greatly change the relationship between existing modes and each new system tends to create its own market. In dealing with potentially new modes, demand data must concern itself with user desires and needs. Modal split is very difficult to determine, and the planner should concentrate on sytem characteristics of the new mode rather than the preferability of the new mode to existing modes.

The limitations of demand models should also be kept in mind. One such limitation is due to the fact that the data used in determining parameters for these models comes from a steady-state situation. Stated another way, the data are obtained at a time when the riders are performing in a basically habitual manner. The effect of having a model based on this type of data is that it can not be effectively used to predict rider behavior to changes in the system. In engineering terms, this would be equivalent to using a steady-state model to predict the transient response of a dynamic system.

This section has pointed out that planning can be considered as an interface between the old transportation system and the new. The validity of the models, especially user and nonuser acceptance models, is extremely important if the planning process is to be an effective interface between old and new.

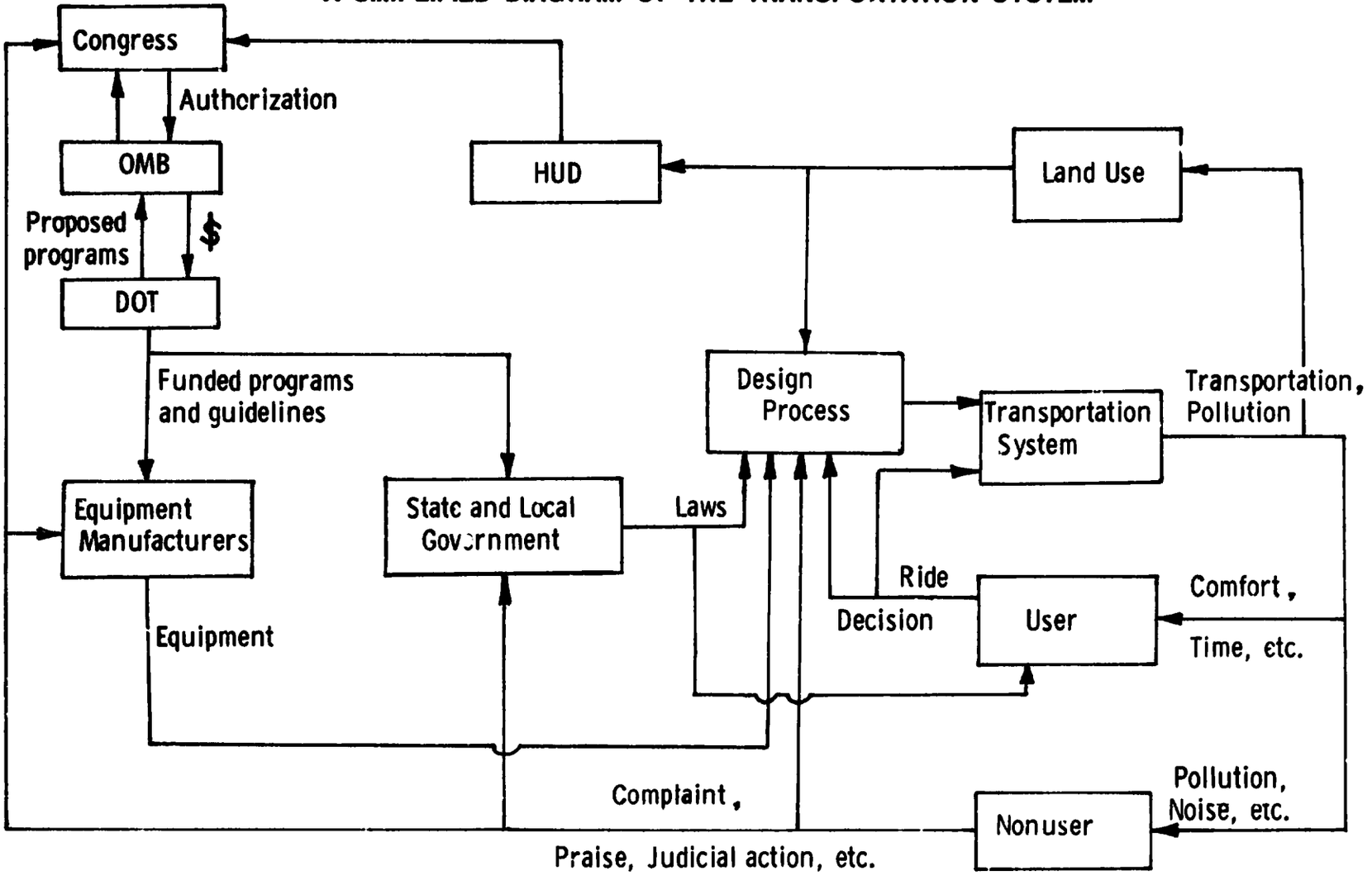
B.2 Feedback Problems

The transportation system is composed of transportation hardware and software, users, nonusers, and a multitude of other components. It is an excellent example of a complex circulatory or feedback system. There are loops at all levels within the structure with innumerable interactions between the loops.

The complexity of the feedback loops within this system is shown in the simplified diagram of Figure 5.5. The ultimate effect of the operation of the transportation system is a feeling of acceptance or rejection on the part of individuals (both users and nonusers). The problems discussed in this section have a feedback systems orientation and have a negative effect on acceptance of transportation by individuals. Before discussing the individual problem areas it is necessary to distinguish between positive-feedback and negative-feedback.

"The negative-feedback loop is the one most commonly found in the literature of systems theory and is almost the only one discussed in engineering. But it is the positive-feedback loop that generates all growth processes, whether they be biological or economic. Negative-feedback loops are goal-seeking, tending to regulate the system toward some objective. Positive-feedback loops are goal-divergent, tending to depart exponentially from some point of unstable equilibrium. But the positive-feedback character, which gives the positive loop its growth behavior, comes not only from structure but also from numerous variable factors around the loop. These factors are often set and controlled by other loops in the system. As these factors change, the positive-growth loop can be depressed in its regenerative characteristics and brought to a neutral point marking the boundary between positive- and negative-feedback behavior. If the loop is pushed into the negative-feedback region, the loop begins to generate exponential collapse toward the original reference point from

FIGURE 5.5
A SIMPLIFIED DIAGRAM OF THE TRANSPORTATION SYSTEM



which it was diverging. The behavior of social systems is intimately related to this interaction between positive- and negative-feedback processes." [5, p. 108] Positive-feedback loops are not in and of themselves deleterious. However, positive-feedback loops, when operating without control, often produce effects which individuals consider undesirable. This is not to say that negative-feedback loops do not also cause undesirable effects, but these effects are often of a subtle nature. The examples in this section point up the feedback aspects of several problems which tend to restrict the arteries of effective transportation design.

B.2.a The Land-Use Spiral (Positive Feedback)

The growth of a city is not necessarily bad. Only when that growth contributes to a poor quality of life for some residents does growth become a villain. Transportation and city growth or urbanization are closely coupled. When this land-use-transportation expansion spirals in an uncontrolled manner, human factor problems are generated. These problems are a bottleneck for the effective use of transportation as a means of achieving societal goals.

The essence of the land-use spiral is contained in a chronological description of Chicago. "The story of metropolitan Chicago is a story of growth and change. Over the last hundred years, the prairie shore of Lake Michigan has been changing from rural to urban with ever-increasing speed. Grasslands have changed to crop lands and crop lands to the land supporting urban population and its institutions. The village has become the city; the city has given way to the metropolis; and *the metropolis is growing out* toward connection with other metropolitan areas . . ." [6, Vol. III, p. 1]. Unmentioned in this description is the fact that this growth could not have been achieved without provision for adequate transportation facilities.

"Is the quality of life of today's Chicagoan better than that of one hundred years ago?" The answer to this qustion in many respects is no. Following this negative reply, another question must be asked: "Could transportation have been used to maintain or improve the quality of life of a hundred years ago?" The answer to this question is yes. The point is that if a land-use policy is promulgated which attempts to guarantee a certain level of quality of life than transportation can be used to implement that policy. By the same token, if no land-use policy exists for guaranteeing quality of life then transportation will be provided on the basis of demand with little thought given to subsequent quality of life.

Two views of the relation between land-use and transportation have emerged. One view is that transportation is essentially a utility to be supplied on demand. Such a viewpoint spawns an uncontrolled positive-feedback transportation-land-use process. Additional transportation generates new residential land which generates more demand for transportation. The end result of this type of process is urban blight and suburban sprawl. This viewpoint on transportation has been the accepted perspective for generations. This point of view coupled with modal emphasis such as the Highway Trust

Progress?

Johnny on the Spot.

Fund has generated excessive pollution, congestion, danger, etc.

The second view of transportation is that it should be considered as a tool for implementing higher level goals. The logical place for establishing such goals is in land-use. Appropriate land-use policies, with transportation as an implementation device, would be effective in providing an adequate quality-of-life for society.

B.2.b Organizational Feedback Loops

As seen in Figure 5.2, the starting point of any design process is a stated need or goal. A system is then developed for meeting this need. In transportation systems one of the largest problem areas, a major stenosis of the planning artery, is lack of policy. The basis for policy in many cases has been "decision by indecision."

This lack of clear policy on transportation is similar in effect to the uncontrolled transportation-land-use spiral. Without a clear policy the main generating force for transportation is demand. Thus, a demand for more transportation is met by providing a larger quantity. With demand playing the predominant role, the mode of new transportation is quite often the mode with greatest popularity at that moment. This demand orientation has often led to urban blight and other deleterious effects which have been discussed in previous chapters.

Government must take a more active role in promulgating policy in this area. Policy making of this sort is quite often a matter of moral judgment. Someone with appropriate authority must decide for example whether land developers are more worthy of subsidy than are the poor in inner city areas. The result of these moral judgments will be a statement of policy that either propagates the current transportation land-use spiral, to the advantage of developers, or attempts to provide for such societal needs as mobility for disadvantaged people.

A problem area that is second only to lack of policy is the lack of effective feedback in the transportation design process. Several feedback paths are shown in Figure 5.5. However, these paths are often disguised and the individual is not aware of their existence. A primary reason for this is that individuals can not easily visualize transportation and land-use as a "system." If individuals are to participate, they must know of the alternatives available for community development and be aware of the methods by which they may voice their opinions.

Several approaches are available for overcoming the tendency of political bodies to respond more readily to those with direct interests—such as building roads to enhance the interests of large property owners—rather than those indirectly affected—such as those whose "life styles" are eventually influenced by the long run effects of the transportation pattern. One approach is an extensive educational program to include both a greater emphasis in schools on how transportation is related to the growth and life of cities and more specific educational campaign (to include public hearings, television seminars and debates, and the like) in connection with the adoption and changes to land use plans for the community. The "ecology" movement has demonstrated that citizens groups can be effective in focusing attention on long-run indirect effects of our economic development. This focus can be extended to the question of how we use transportation and land use to give some direction to our economic and social development. The goals and guidelines upon which zoning and transportation plans are drawn would hopefully be oriented more towards improving the **quality of life** rather than improving certain property values.

Part of the problem, as we have mentioned, is that immediate interests of **voters** as well as special business groups may be those which govern transportation and land use decisions. It is assumed here that the narrow perspective can be mitigated when enlightened voters are allowed to participate in **long run** plans for community growth.

In this chapter, in addition to listing specific bottlenecks to better transportation management, we have pointed out that transportation **can** be considered from a systems point of view. With this perspective many problems of transportation can be considered on the basis of common characteristics, e.g., interface or feedback. Looking at problems from a systems point of view is the first step in applying the systems approach to transportation design. Use of the systems approach in **future** transportation planning is considered in the next chapter.

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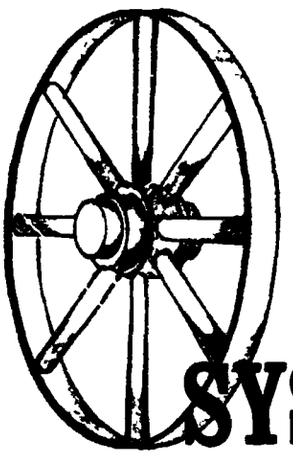

SYSTEMS DESIGN: METHODOLOGY for TRANSITION

6

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6.1 Introduction

Chapter 5 introduced the concept of a circulatory system in our society. This system has produced our transportation network. In an ideal and simplistic sense, a new mechanism of the future would take human needs as a basic input, process these needs in confirmation with a land use policy, and, then, produce a transportation system matched to the needs.

In the previous material we have shown that the existing mechanism is less than ideal. Furthermore, some believe that, if left to produce transportation systems without control in the future as it has in the past, this mechanism will not only be less responsive to human needs, but it will be deleterious to them.

Although we are not able to define a complete, pragmatic, new mechanism, which is capable of accomplishing the idealized transformation of human needs into transportation systems, we are able to point to some improvements which can be made in the existing **machine** and to propose steps and principles which will be useful in making the transition toward a more perfect one.

The ideal systems design methodology is an orderly procedure which outlines the necessary steps to accomplish the design of a device or system as a solution to a definite need. We intend to make our suggestions within this system design framework. Certain prerequisites must be satisfied prior to implementation of the method.

6.2 Prerequisites to the Application of Systems Design Methodology

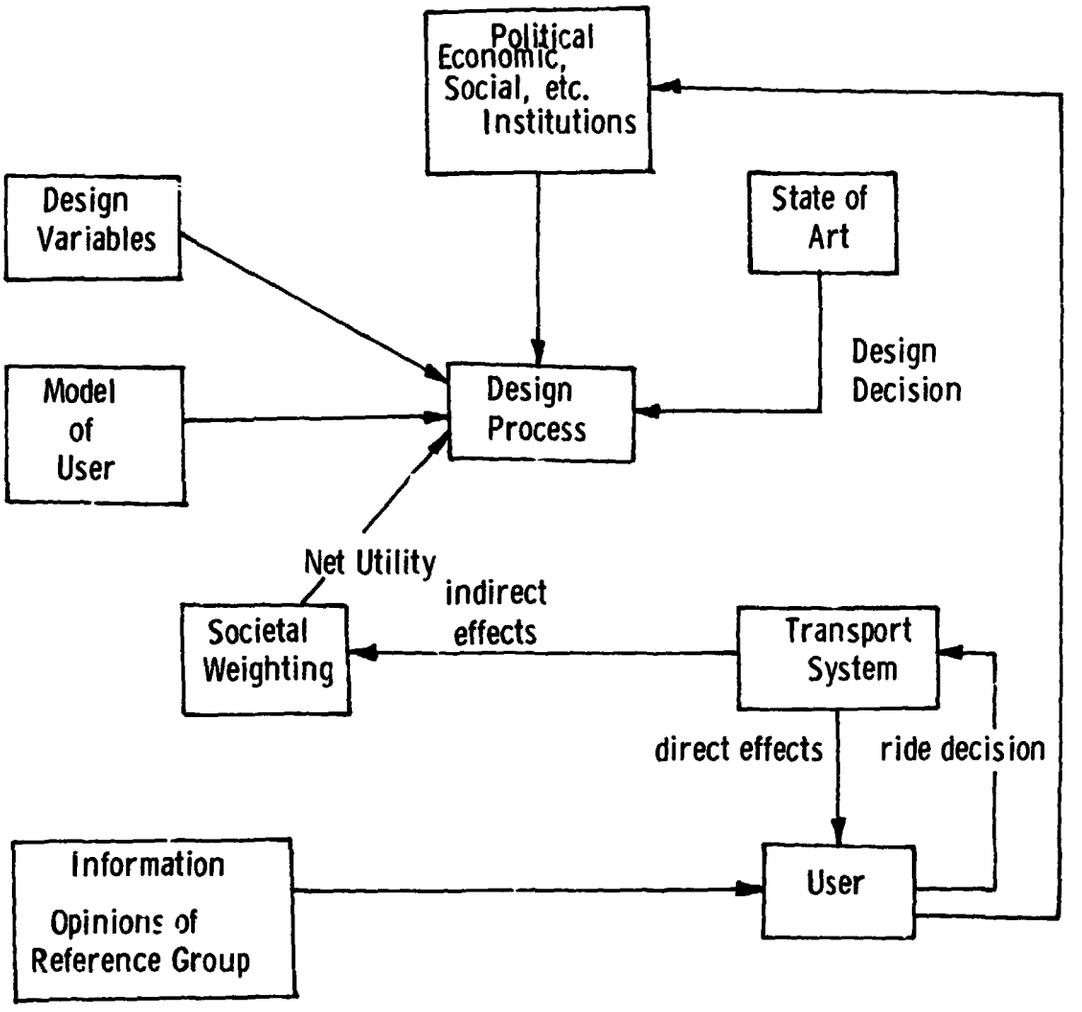
Understanding, goal definition, and organization are the essential precursors to application of the methodology. Clearly, understanding of the factors and forces which exist in the current mechanism is necessary before any action can be taken or proposed. Understanding is itself a prerequisite to formulating goals which will lead to improvement and it is a prerequisite to the creation of an organization which can implement the methodology.

6.2.1 Understanding The Mechanism

The type of understanding necessary for the task at hand is illustrated by several examples in later paragraphs. [Understanding the identification of social, political and economic institutions and groups most closely related to land use and transportation planning.] These organizations are defined in this work as the elements of the system. These elements interact with each and other institutions as well. Understanding is also the identification of these interactions. Such interactions or connections we will refer to as the structure of the system.

Figure 6.1 represents an attempt made early in the project to develop an understanding of the transportation complex. Although it is rather crude, it illustrates the

FIGURE 6.1
AN APPROXIMATE VIEW OF THE TRANSPORTATION COMPLEX



notion of the elements of the mechanism, which are the boxes, and the notion of the structure, which is the network of lines with arrowheads. It shows the user and his relationship to the transportation system both as a customer and as a member of society.

Even at this crude level, the understanding of the exact nature of the relationships among the elements and the clarification of the internal structure of the elements themselves is a complex task. However, that very complexity is an argument for the necessity of understanding. We have all too much evidence that "solutions" based on limited, "partial" analysis tend to aggravate rather than alleviate our transportation problems.

Instead of alteration we now go beyond that crude representation to some examples which illustrate the type of understanding we believe is necessary.

Example 1: Automobile Safety

Of all transportation modes the automobile seems to be the most responsive to human wants, providing flexibility, prestige, privacy among others. Yet the automobile has not been satisfactory from a safety standpoint. Evidently the rewards to the manufacturers for innovations leading to safer automobiles have not been sufficient to cause them to aggressively design in this direction. The buyers have not responded to "safer" cars by buying more of them. Nevertheless, many

citizens will agree to the seriousness of the slaughter on the highways.

In this case the avenue to satisfaction of a human factors need has proceeded through the political structure of our society rather than through the private economic sector. This has required the perception of that need by Congress which established the National Highway Traffic Safety Administration (NHTSA). This group has developed rules which require vehicle manufacturers to incorporate safety devices in their products. The essential relationships are illustrated in Figure 6.2.

Apparently the citizen reacts in a more ideal sense as part of a voting group than he does as part of a buying group. However, he does not vote directly on the safety issue himself but delegates that responsibility to his elected representatives. Thus, the connection in this situation between the citizen and the action of Congress is tenuous. Congress evidently acts as a group according to a set of ideals which is higher than that of the citizen at least when the citizen is an economic decision-maker.

To carry this example a little further, NHTSA has set rules for future automobile models which will require passive protection of the occupants for a head-on collision up to certain speeds. This is a reflection of the fact that a small percentage of citizens in cars actually use the belts which the manufacturers are now required by law to install. The decision has been made that if the citizen will not protect himself then the manufacturer will be required to protect him whether he wants it or not. This is clearly a value judgment rather than a response to voter clamor. It illustrates the protective "big brother" attitude which exists in some government agencies.

The reader is reminded that the purpose of this example discussion is not the example itself or the accuracy of the assertions but that **understanding** such relationships is essential to allow wise adjustment of the mechanism. The pre-existing economic chain on the left side of the diagram has been influenced by the adjusting mechanism on the right. Presumably that addition to the mechanism was a wise one.

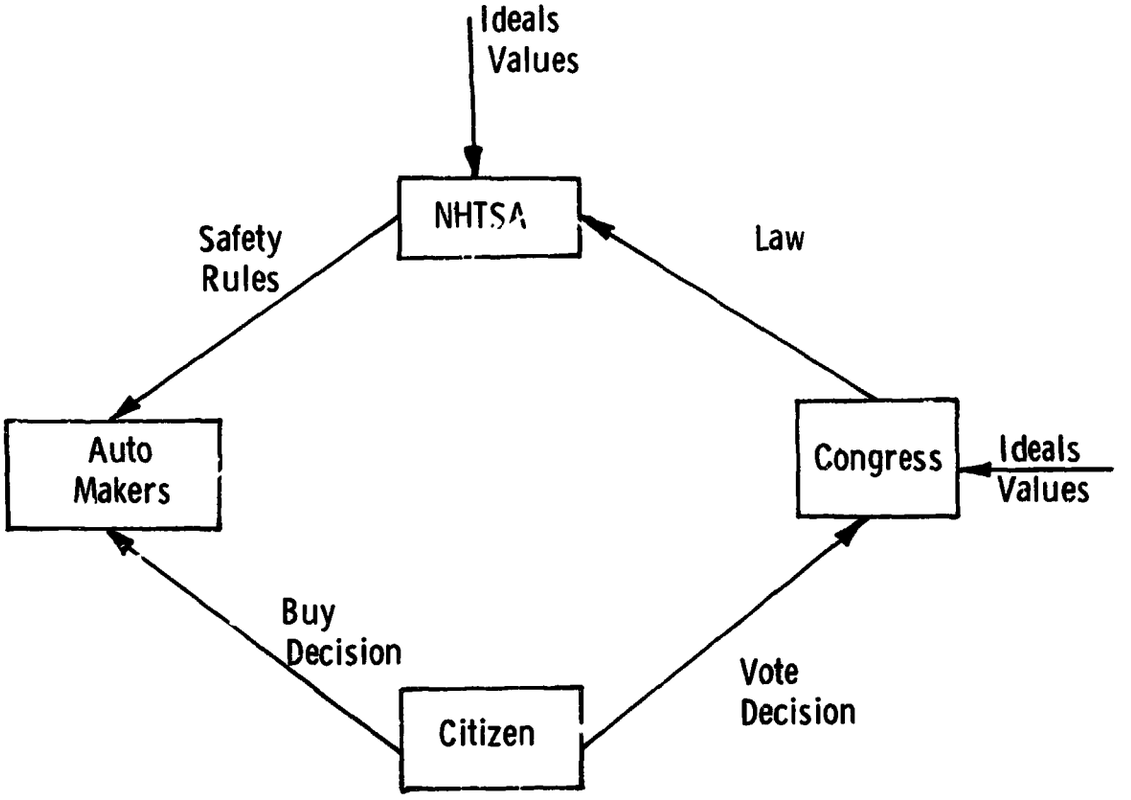


FIGURE 6.2
AUTOMOBILE SAFETY MODEL

Example 2: The Land-Use, Transportation Spiral and Zoning

Our earlier analysis of the relationship between transportation decisions, land use and economic development has demonstrated why a broad interdisciplinary approach is required. We have described the effects of the transportation-demand spiral in engendering dislocations, in economic activities, and in distorting the demand for new transportation facilities. We have designated four "roadblocks" in the path of more rational decision-making. First, local governmental units are Balkanized, and since land use and transportation have spillover effects, these separate units often have conflicts of interest. If each has some degree of veto power over transportation decisions, any coordinated effort which impinges on one area's interests will be defeated.

Secondly, voters themselves tend to look at their own immediate wants rather than the social benefits and costs associated with long-term community development. Since at any specific time, most of the land use and transportation variables must be taken "as given," voters tend to vote according to their own **immediate** interests, i.e., "what action will improve my drive from my suburban home to my job in central city?" A third and related problem is that individuals cannot easily visualize transportation and land use as a "system." If they are to participate they must know of the alternatives available for community development and be aware of methods by which they may make input into the decisions.

Finally, we have observed that the political institutions respond more readily to alliances with direct economic interests than to the long-run community needs which feature indirect benefits and little incentive for organized political participation. We recognize that the zoning which accompanies land use planning can be used to enhance the property values of certain interest groups at the expense of optimal development patterns.

Design of choice mechanisms which will allow for appropriate resolution of conflicting interests and for the expression by citizens of their community development goals require considerable insight into the incentive patterns of the current economic and political "actors" in transportation and land use decisions.

Example 3: The User Mode Acceptance Mechanism

In evaluating other modes of transportation, the automobile owner uses his car as a reference point. The motorist takes the benefits conferred on him by his chariot—the levels of comfort, service, cost, convenience—and then decides if the public transportation mode, such as bus or train, can match it. If it can, he will probably leave his car at home.

Research has shown that Americans in the mid-twentieth century are motivated to maximize their own personal gains, and those of their families, even when society suffers. Thus, the fact that automobiles contribute to pollution will not make the average citizen decide to take the train to work, if his car is faster and more comfortable. Future attempts to alter commuter behavior clearly depend on this understanding for success.

As a final point in this "understanding" section we refer back to Chapter 5 which illustrates that the transportation complex is imbedded with many feedback paths and interfaces between elements. Furthermore, it is not a static, but a changing and evolving system. Therefore, not only does understanding require a broad point of view, it requires a flexible one which can adjust to new situations and new influencing factors.

6.2.2 Goal Definition

We have discussed the lack of national transportation goals particularly with respect to a national land-use policy. Our intent here is to show that it is not enough to define or point to problems but that it is necessary to formulate goals which when achieved will solve the problems. In some discussions of system design, the formulation of goals has been included as part of the methodology. It appears necessary in our political system to define goals prior to creation of an organization which will effect them. Therefore, we have chosen to treat it separately.

As an illustrative example consider the problem of the poor who live in the peripheral area of the city and who are required to travel to another location near the outer edge of the city. Since this group of people does not own automobiles, it cannot travel in a circumferential direction (except by taxi which is beyond their means). This immobility is due to the fact that major public

transportation routes are radial in nature in order to handle the large volume of suburban city commuter traffic.

If the goal of the city is to reduce congestion, then the needs of this group will not be met because they do not currently contribute to congestion. Since they do not form a major component of auto traffic, decisions based on a cost effective analysis will not lead to solution of their problem.

This fact leads us to the concept of the mobility profile which is shown in Figure 6.3. It classifies citizens according to their work and home locations as the base axes indicate. Upon the grid thus defined is superimposed a vertical distance to represent the mobility of a particular category. The cluster of rectangular solids represents a mobility profile of the city. Mobility in this case could be defined as the opportunity to make the work-home trip within a certain time and at a cost which is a certain percentage of the income.

A logical goal for a city would be to set a certain minimum level of mobility for all its citizens. This does not mean that all citizens should necessarily have the same mobility but that no citizen should be without a minimum amount. Such a goal would provide a definite input which a systems design team could attempt to meet. It is also apparent that such a goal involves value judgments since the existing economic forces would not accomplish it.

6.2.3 Organization

From the previous chapters, it is apparent that transportation decisions should be made by an interdisciplinary group. However, at the small city level that group might only be one man or a group of part-time men. It seems that in order to obtain the resources necessary to finance an interdisciplinary group, transportation planning must be done at the county, regional or state level. Therefore, such agencies should develop guidelines or policies which would help the smaller segments in their efforts.

Consideration of this concept raises some serious problems. Local communities do

MOBILITY PROFILE

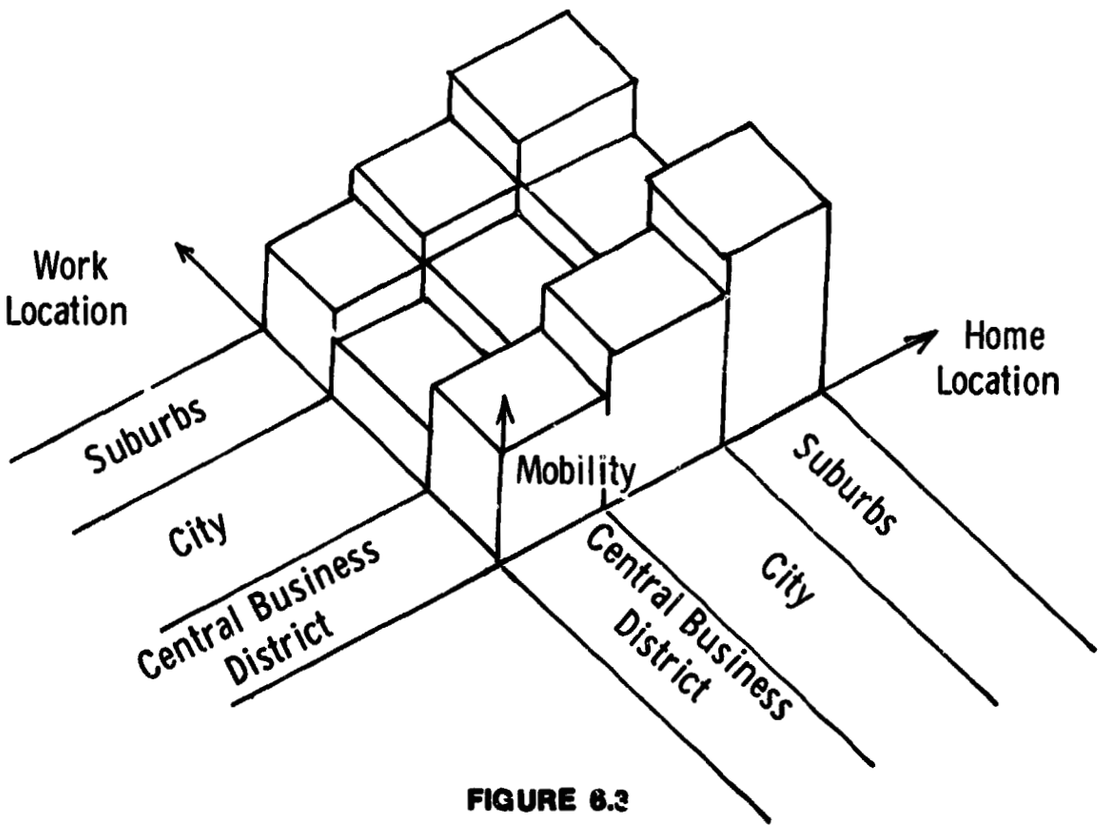


FIGURE 6.3

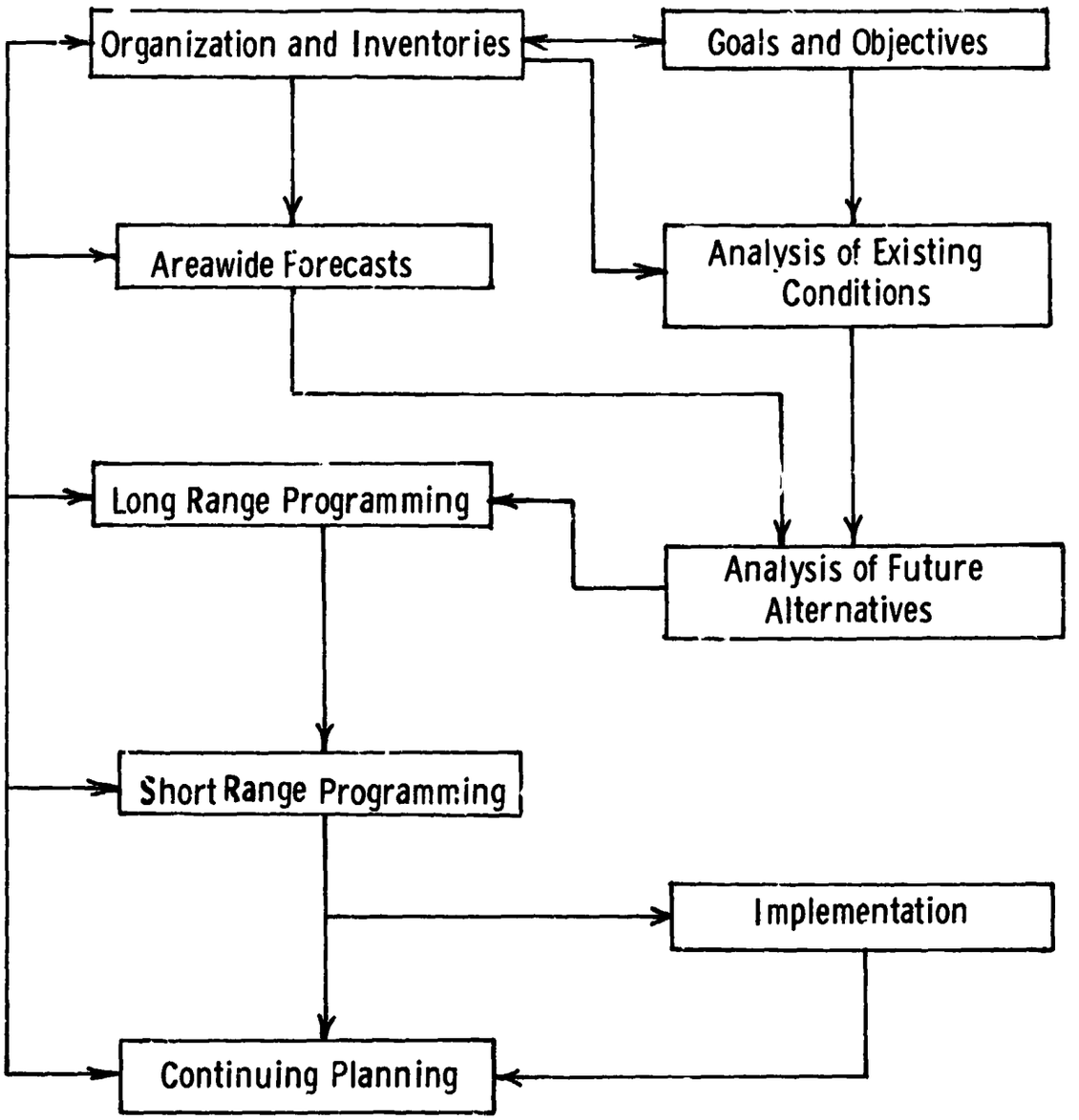


FIGURE 6.4
THE URBAN TRANSPORTATION PLANNING PROCESS

not want to give up their autonomy to a larger organization, yet they do not have the resources to meet their needs. Furthermore, coordination between communities, states and regions is imperative if transportation and land use problems are to be solved. In addition, since value judgments are to be made the citizenry should have some influence.

Current Councils of Governments have a planning function, but they do not have authority to implement their plans. There is a temptation to suggest that they be given this authority, but the question of autonomy is again raised. Perhaps a system of checks and balances which is similar to that existing at the national level could be applied here. Organization at this level is in itself a very challenging interdisciplinary design problem. Development of guidelines for such organization is an essential goal to be considered at the national level.

We have observed several factors about

interdisciplinary studies which should be considered in developing an organization. First, there is a tendency for people to separate and consider problems from the viewpoint of their own narrow disciplines. This separation results in an effort which is not really interdisciplinary at all but is a collection of many different points of view. Second, there is a tendency to become enraptured with the details of various aspects of the problems and consequently to lose sight of the main goals of the group.

6.3 Systems Design Methodology

In Chapter 5 a general introduction to systems design was given. It provides a procedure by which goals can be reached if there is an organization in which the procedure can be imbedded. It is shown in general in Figure 5.2. And it is shown in a transportation planning context in Figure 6.4 [1].

We wish to emphasize several main parts of the activity. First, it is intended to be a creative one in which solutions to meet the goals are synthesized by whatever means possible. Secondly, these solutions are examined by predicting their consequences. Thirdly, an evaluation of these alternative solutions is made to determine the best one. Finally, tasks to accomplish the solution are defined and time scheduled to accomplish the solutions.

The current procedure as shown in Figure 6.4 has the creative and predictive activities lumped together in the box "analysis of future alternatives." We shall focus on the predictive part.

6.3.1 Predictive Tools

A battery of computer programs is available to the transportation planner to help him predict traffic flows according to the procedure shown in Figure 6.4 and Figure 6.5 [1]. They require a great deal of effort for their calibration and their predictive ability seems limited. These programs are based upon the city transportation flows as they exist currently; therefore, they only predict these steady state flows. However, one need of the designer is to predict the consequences of new modes or radical changes in the scheduling of new modes.

The references show several theories of user mode choice which could be used, but there seems to be very little data to validate such theories [2]. Development of predictive tools which model human behavior in relation to transportation seems to be a continuing need for the future.

We suggest two ways in which this development can be aided. First, new transportation systems which are implemented should be accompanied by pre-project and post-project data acquisition in the form of attitude surveys which are specifically designed to acquire information which will validate or invalidate theories available.

The use of this data is shown in Figure 6.6. The general idea is that the new transportation mode represents an input to the community. The community will respond to this input in a particular way which the model should predict. However, the model will undoubtedly be inaccurate; therefore, there will be an error between the actual response and the model response. The model developer can then use this error to modify the model so that it will predict more accurately.

The second way to gather information which can be used to improve the predictive models is to construct demonstration projects such as the one at Morgantown, West Virginia, which are specifically designed **not only** to demonstrate hardware but to shed light on predictive models of human behavior. We have expanded this idea into a rather "grand" experiment proposal.

6.3.1.1 The Experiment

An experiment is proposed that would involve transforming selected urban areas into comprehensive transportation planning realities. For example, in the hardware development of a new design, it becomes necessary at a certain stage to build a prototype in order to be able to anticipate all of the inherent problems and benefits involved with the design. In a transportation system, with all its human and societal aspects, it is even more important to "construct" prototypes.

Specifically, the experimental urban area or areas would be used to do the following:

A. **Gain significant insight into the response of people to new transportation concepts or hardware.** Current transportation planners use models to predict demand upon various existing modes of transportation. These models are capable

of providing short-range extrapolations of conventional systems. Models which provide a prediction of usage of new transportation modes or configurations are not available. A part of the reason for this lack of adequate models may lie in the fact that the new modes are only fuzzily conceived by the potential users so that attitudinal surveys relative to them yield weak predictions.

B. **Test new Hardware designs under conditions of actual use.** Will the new modes actually stand up to the use anticipated? Considerations should include mechanical wear as well as the new system's compatibility with the utilities and physical configurations of the use area.

C. **Test new ideas in organizational concepts.** In other words, explore advantages to be obtained by efficient utilization of the software of transportation, i.e., scheduling, information to user and non-user, fare collection, intermodal and intramodal transfers, and others.

D. The questions as to the optimum administrative institutions and as to their goals, procedures and financial resources, need to be answered.

What has been suggested above is that an urban area be used for a full-scale investigation of transportation. What this does not mean is that a given urban area be given a once-and-for-all transportation system. Rather, it would begin with a comprehensive plan. Next, full-scale construction and implementation of a short-to-medium range solution system would take place. This step is followed by replanning and reimplementation

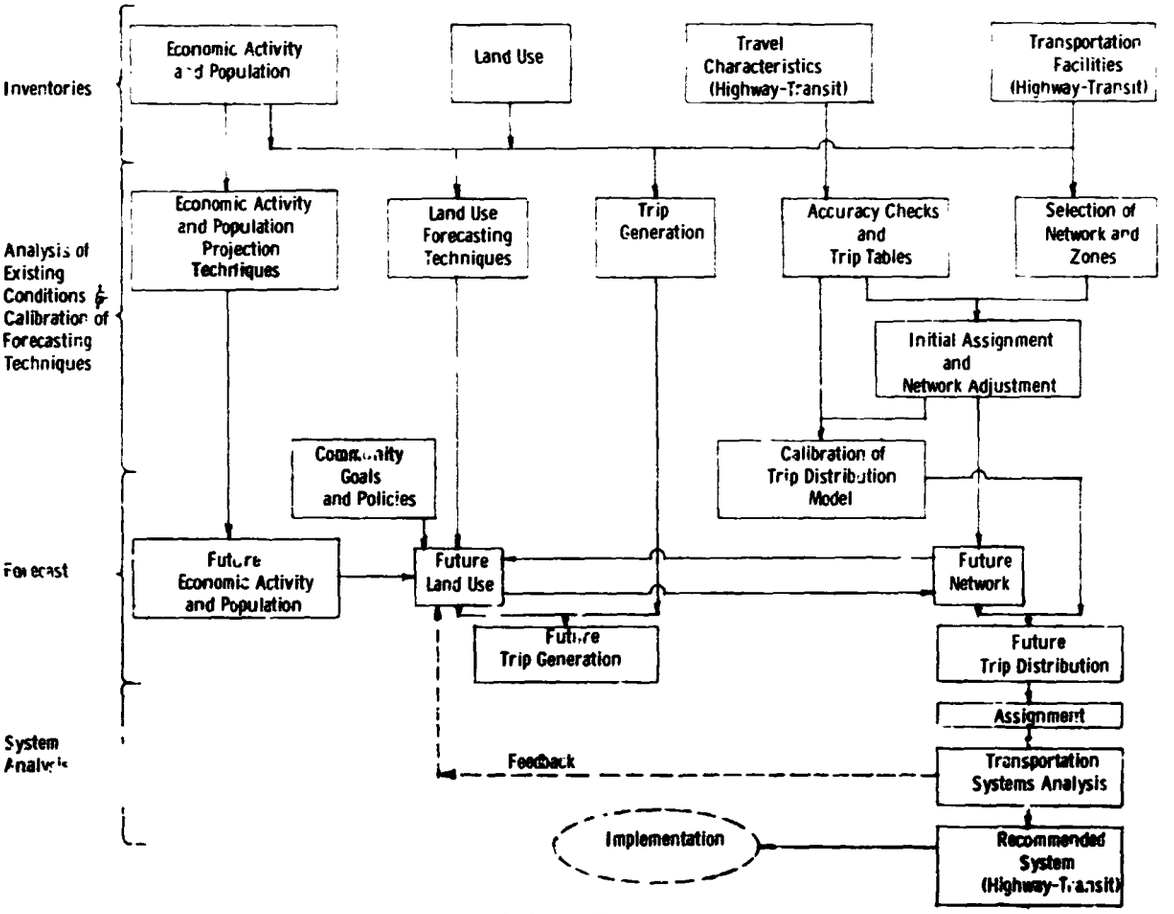
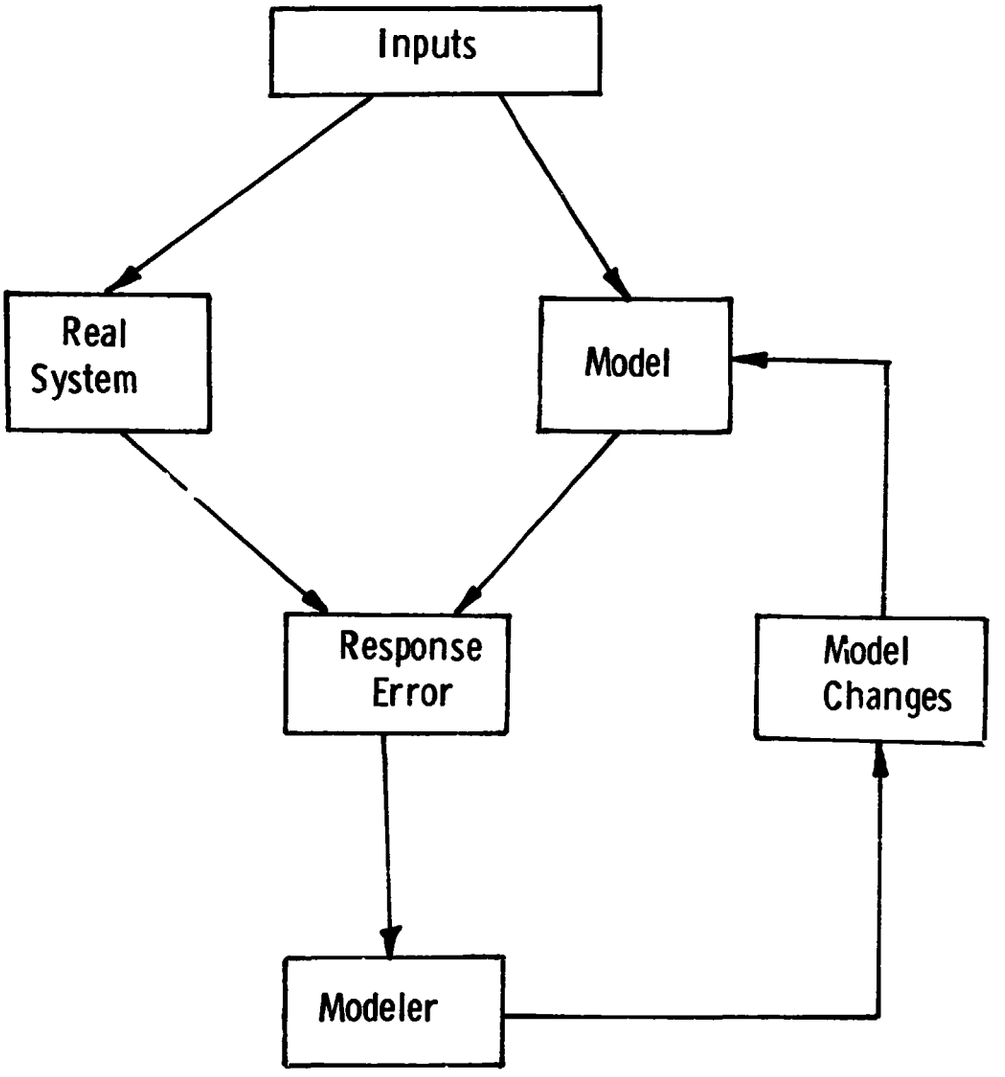


FIGURE 6.5
THE URBAN TRAVEL FORECASTING PROCESS

FIGURE 6.6
THE MODEL IMPROVEMENT PROCESS



with larger solutions frames (more global form) in mind. It will be incremental if such systems require incrementality.

Considerations

A number of considerations should be incorporated into the experiment in transportation. A summary of them is given below:

A. It must be implemented on a full scale with inclusion of the real software and hardware of a transportation system. The goal and constraints of this system would be specified and all modes within this system would be considered.

B. It must be overtly designed to provide the maximum information which can be transferred to transportation planning agencies throughout the country. It should include extensive attitudinal survey work prior to its inception and attention to gathering information on mode acceptance for new modes—similar information should also be gathered after its construction.

C. Since transportation system time

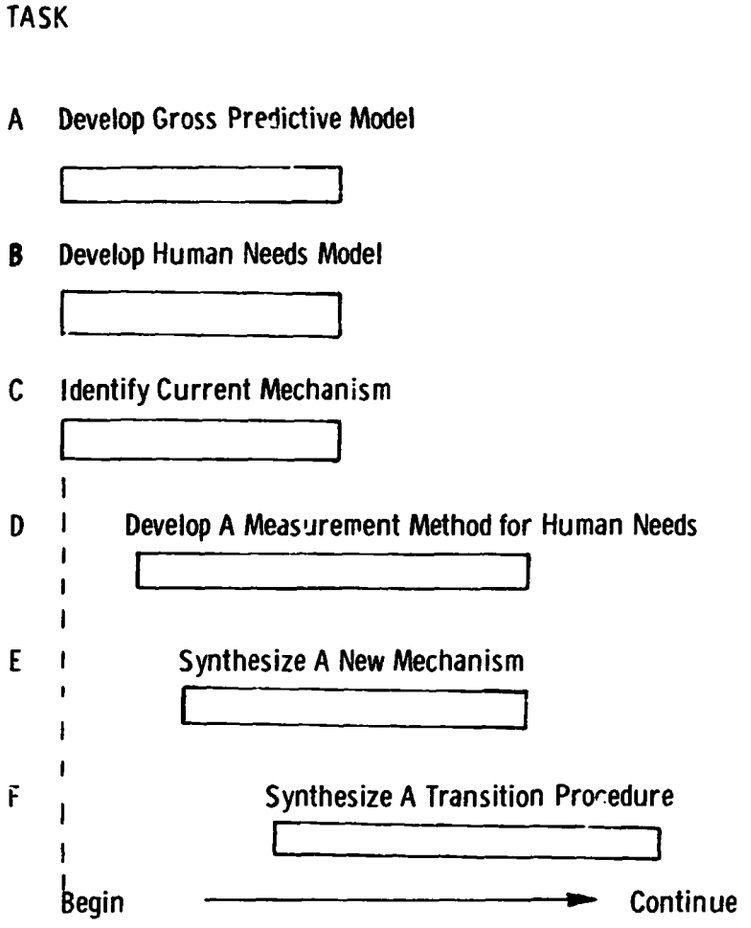


FIGURE 6.7
IDEALIZED SEQUENCE OF TASKS NECESSARY FOR TRANSITION

scales are long, it is likely that other cities will be attempting solutions while the experiment is in progress. Therefore, information output should be continuous.

Candidate Urban Area

The site for such an extensive experiment is difficult to choose because of political considerations. However, Washington, D.C., and its suburbs might be an ideal site. It could be easily justified that this area ought to be the showplace of the nation. It certainly has the characteristics of many of the cities with transportation problems. Its selection would circumvent many of the political problems in choosing an area. The effects of the experiment would be highly visible to the federal decision-makers. And finally, there is little doubt that Washington has a substantial transportation problem.

6.4 The Ideal Mechanism

The ideal mechanism is hypothesized to be constructed of political, economic and technological components. These components are so arranged that the mechanism produces or modifies transportation systems so that human needs are met in an optimum way. Such a grandiose concept might have a "Buck Rogers" connotation but it would serve as a hypothetical testing ground for creative approaches to the problems. Furthermore, the ideal serves as a reference from which to measure the deficiencies in the actual. Although we have not even defined the ideal system, in previous chapters we have

suggested some things which should be contained in it.

An idealized sequence of the tasks in which would lead to the design of such an ideal mechanism, is shown in Figure 6.7. Although a time sequence is indicated, most of the tasks should continue indefinitely. Listed below are definitions of these.

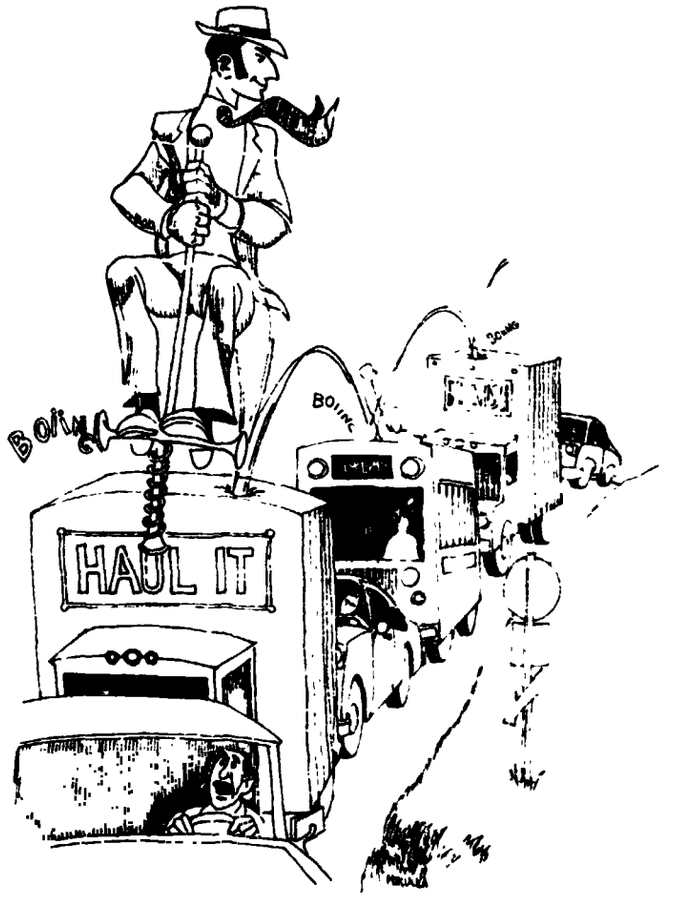
A. Develop reliable methods for predicting those factors which most directly affect transportation systems. In very general terms such factors are population, economy, land use and transportation itself. These general factors are complex as are their interactions. This is, therefore, a complex modeling task Such a task was outlined in the Integrated Transportation Study of California in 1965 as shown in Figure 5.4.

B. Identify and relate human needs to the factors above. This is also a complex modeling task. It is performed at a basic human needs level rather than at the gross systems interaction level of **A.**

C. Identify the existing political social and economic institutions which exert power and influence on the economy, land usage and transportation, and determine the interactions between these institutions.

D. Determine methods of data acquisition which will reflect the identified needs of **B.** If the needs of **B** are to be considered, they must be measured or at least inferred. Measurements at the gross factor level of **A** may be the only possibility in some instances.

E. Synthesize a system which will attempt to drive the states of land usage, economy and transportation in a direction which will cause the needs of **B** to be better satisfied. This system must clearly allow for the protection of individual rights and



liberties while at the same time meeting individual and collective needs with as much efficiency as possible. It obviously must be based on high moral principles. It would rely on the models developed in **A** and **B** to predict the consequences of design changes. It would also include procedures to allow the citizenry to be involved wherever value judgments are made.

F. Synthesize a procedure which will allow upgrading or modification of the current mechanism defined in **C** to that developed in **E**. This procedure requires transition in an orderly and effective way. During the transition, a desirable goal is to have the states of the economy, land usage, and transportation progressively improving to meet the needs.

An idealized relative sequencing of these tasks is shown in Figure 6.7.

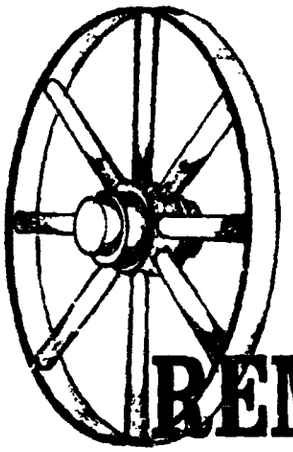
6.5 Conclusion

In conclusion, effective transition toward a solution of our transportation related problems requires understanding of the varied forces and factors which influence our system, selection of goals to solve the problems, formulation of an organizational structure which can work toward the goals, and application of a logical orderly procedure to accomplish those goals. Considerable work is still to be done in the design for a **general systems approach** to land use and transportation planning. We anticipate that even when such work is accomplished the resulting design can only act as a blueprint for studies which must be carried out by interdisciplinary teams on regional and metropolitan levels. This is because the past economic development, the available natural resources, and the future needs and goals of different regions and metropolitan areas call for their own unique solutions.

References

1 Federal Highway Administration. March 1972. *Urban Transportation Planning.*

2 Reichman, Shalom, and Stopler, Peter R., 1971 *Disaggregate Stochastic Models of Travel Mode Choice*, Highway Research Record, No. 369.



REMOVING the COMMOTION:

CONCLUSIONS and RECOMMENDATIONS

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Transportation has played many roles in our history. From its service as a woof to the warps of economic and social integration and its function as a distributor of people and goods to local destinations to its part as a determinant in growth and development patterns, American transportation has helped to weave the pattern of our culture. However, our transportation system has created as many problems as it has solved. One need only be a casual observer to realize some of these problems.

Goals and Policies

If one role of transportation is to provide mobility, our system has only been partially successful. A look at any large urban center will provide much documentation of this fact. For those who can afford automobiles, bumper-to-bumper traffic is hardly mobility; for those who cannot own cars, public transit is, more often than not, inadequate for mobility. One of the reasons for this lack of mobility is that at this time in our history we as a nation have not defined the role of transportation. We, therefore, recommend that THE ROLE OF TRANSPORTATION IN OUR NATIONAL DEVELOPMENT BE DEFINED IN A DUAL SENSE AS (1) A SERVICE TO PROVIDE NECESSARY MOBILITY AND, (2) A TOOL FOR LAND USE PLANNING AND DESIRABLE SOCIAL AND ECONOMIC DEVELOPMENT.

Mobility is not enough. Transportation's traditional role as a determinant in growth and development cannot be permitted to continue unchecked. We have a limited amount of land which must continue to serve a growing population. A national transportation policy is urgently needed but we recommend that CONGRESS GIVE FIRST PRIORITY TO THE PASSAGE OF A COMPREHENSIVE NATIONAL LAND USE POLICY AND PLANNING ACT, AND THAT TRANSPORTATION POLICY AND PLANNING BE MORE CLOSELY COORDINATED WITH LAND USE PLANNING, AS A LAND USE PLANNING TOOL. Transportation planning and land use planning are thus inseparable and Congress must do all within its power to integrate these planning operations.

Recently, the President of the United States has proposed a reorganization of the executive branch of the government. This proposal seeks to eliminate the Department of Transportation which is presently assigned the task of developing a unified National Transportation Policy, and to assign DOT's functions to new departments. We find the proposal premature and recommend that CONGRESSIONAL ACTION ON THE PRESIDENT'S PROPOSAL BE WITHHELD UNTIL CONGRESS HAS COME TO GRIPS WITH CRITICAL ISSUES RELATING TO THE ESTABLISHING OF A NATIONAL LAND USE POLICY AND NATIONAL TRANSPORTATION POLICY TO INSURE THAT ANY REORGANIZATION WILL BE DESIGNED FOR THE EFFICIENT IMPLEMENTATION OF THESE POLICIES.

We are not, however, recommending against an eventual reorganization of the executive branch. After Congress and the Executive Branch have thoroughly studied and evaluated the relationship of national goals in land use and transportation, we recommend that THEY REORGANIZE EXECUTIVE DEPARTMENTS AND AGENCIES TO ENHANCE **COORDINATED** LAND USE AND TRANSPORTATION POLICIES. REORGANIZATION WOULD INCLUDE A NEW EXECUTIVE DEPARTMENT (OR DEPARTMENTS) WITH RESPONSIBILITY FOR ENABLING COMMUNITIES AND REGIONS TO PARTICIPATE IN THE PLANNING AND CONTROL OF LAND USE AND TRANSPORTATION AND THEIR EFFECTS ON THE SHAPE OF COMMUNITY, REGIONAL, AND NATIONAL DEVELOPMENT. We anticipate that one relevant goal will be to improve our quality of life by avoiding many of the dislocations accruing with unguided economic development.

But where will these policies come from? Congress has traditionally waited for the executive branch to formulate a policy which it (Congress) approves, rejects or amends. The burden for a transportation policy ought not to lie with the executive branch but with the legislative sector. To this end, we recommend that a JOINT HOUSE-SENATE COMMITTEE BE ESTABLISHED TO FORMULATE POLICY AND TO COORDINATE ALL TRANSPORTATION MATTERS. To aid Congress in determining these policies we recommend that CONGRESS ASSURE ITSELF OF A QUALIFIED PROFESSIONAL TRANSPORTATION STAFF BY UNDERWRITING FELLOWSHIPS FOR COMPETENT SCIENTIFIC AND ENGINEERING AIDES.

By our recommendations above we have implicitly assumed the continuation of the Department of Transportation as an executive arm for the immediate future. We would, however, like to see DOT attempt to move in a

direction which would make it more capable of dealing with our transportation problems. In the area of technical data we feel that DOT should ESTABLISH A **CENTRAL** DOCKET FOR INCOMING INNOVATIVE TRANSPORTATION TECHNOLOGICAL DATA. Only in this way can DOT assure itself of "being on top" of the transportation scene at all times.

For many years, the Federal Government has favored one mode of transit over others. In the last century it was the railroad and now aircraft and especially the automobile receive top priority. Since 1955, the Highway Trust Fund has enabled the automotive mode to grow at the expense of other modes. To correct this distortion, we recommend that THE MODALLY DESIGNATED TRANSPORTATION TRUST FUNDS BE ELIMINATED AND THAT THE FUNDS THEREIN BE AVAILABLE FOR GENERAL TRANSPORTATION PURPOSES TO ENABLE THE DEVELOPMENT OF MORE FLEXIBLE INTERMODAL (OR MULTIMODAL) POLICIES AND PLANNING.

We realize that the traditional argument in favor of such trust funds was that the user paid for his use of the facility. But the fair share cost of highways has **not** been paid for by the trucking industry nor have certain tax losses sustained by local governments been considered in the overall cost of the highways. We recommend that ALL COMMERCIAL MODES OF TRANSPORTATION PAY FOR THE USE OF THEIR APPROPRIATE RIGHTS-OF-WAY IN PROPORTION TO THEIR USAGE, THESE COSTS INCLUDE THE PRICES OF PREPARATION (ROADS, WATERWAYS, AIRPORTS AND SERVICE FACILITIES), OF MAINTENANCE, AND OF LOSSES IN TAX REVENUE TO LOCAL GOVERNMENTS WHICH CONVERT TAXABLE PROPERTIES TO TRANSPORTATION USE. THE BASIS OF THIS COSTING WOULD ALLOW THE SETTING OF TARIFF RATES THAT ARE COMPETITIVE IN THE LONG RANGE. SHORT RANGE INCENTIVES SHOULD BE ENCOURAGED WHERE THEY CONTRIBUTE TO LONG RANGE STABILITY.

Another problem area lies in highway maintenance. The federal government provides most of the capital for highway construction but none for maintenance. Thus, states and local governments are either saddled with huge bills for maintenance or highways simply deteriorate. To overcome this unnecessary situation, we recommend that THE FEDERAL GOVERNMENT PROVIDE FUNDS FOR HIGHWAY MAINTENANCE IN THE SAME PROPORTION AS FEDERAL CAPITAL IS PROVIDED FOR CONSTRUCTION. NECESSARY FUNDS MAY BE OBTAINED FROM THE HIGHWAY TRUST AS LONG AS IT EXISTS.

Community Involvement

While we sorely need a national transportation policy, we are also in dire need of some kind of coordinating mechanism with local (and state) governmental and citizens' groups. The federal Government can set general guidelines but individual geographic areas have different problems and there must be considerable flexibility to permit local areas to implement what they need. That is, what New York wants and needs is not necessarily what Los Angeles wants and needs. Thus, we recommend that in FORMULATING TRANSPORTATION POLICY CAREFUL CONSIDERATION BE GIVEN TO THE ADVANTAGES OF LOCAL PUBLIC OWNERSHIP (AS CONTRASTED WITH PRIVATE OWNERSHIP AND/OR CONTROL OF URBAN TRANSPORTATION SYSTEMS TO PERMIT THE FULLEST EXPLOITATION OF THE SERVICE AND LAND USE PLANNING POWER OF TRANSPORTATION AND TO MAXIMIZE INTERMODAL PLANNING. This recommendation is reiterated in the Executive Summary of the 1972 National Transportation Report which states that the wide variability in modal program emphasis from state to state and from urban area to urban area has led the DOT to conclude that increased flexibility among modes is warranted in future federal aid to transportation programs, both in urban and in rural areas. Indeed, DOT "is committed to a continuing coordinated comprehensive transportation planning process with full participation by local as well as state governments." [1]

Of course, a chronic problem which hinders local transportation planning is that transportation networks cross local governmental jursidictions. Frequently, an urban area can include three states, several counties, and numerous smaller governmental units. Such an agglomeration of political entities too often hinders any kind of regional planning process. Councils of Governments (COGs) function well as planning agencies

1 *1972 National Transportation Report: Present Status-Future Alternative*, 1972. Department of Transportation. Executive Summary, Washington, D.C., July, p. 21.

but virtually not at all as implementation units. The power to implement is lacking, and we recommend the elimination this transportation bottleneck by having CONGRESS PROVIDE FUNDING FOR STUDIES AND/OR RESEARCH AND DEVELOPMENT PROJECTS AIMED AT FORMULATING NEW GOVERNMENTAL ORGANIZATIONAL STRUCTURES, INCLUDING INTERSTATE STRUCTURES, HAVING BOTH PLANNING AND IMPLEMENTATION AUTHORITY TO DEAL WITH COMPLEX METROPOLITAN TRANSPORTATION AND OVERALL COMMUNITY PLANNING AND DEVELOPMENT MATTERS.

But cooperation among political structures alone is not enough. Citizens who are affected in numerous ways by transportation must have a voice in the planning of future transportation systems. Planners, be they urban, transportation or the land use type, MUST SERVE A DUAL ROLE, INSURING, IN THE COURSE OF THEIR PROFESSIONAL RESPONSIBILITIES, THAT NOT ONLY WILL THEY REPRESENT THE PROGRAMS OF THE ELECTED OFFICIALS FOR WHOM THEY WORK, BUT THEY WILL ALSO REPRESENT THE INTEREST OF VARIOUS GROUPS WITHIN THE METROPOLITAN AREA.

To insure a higher level of citizen input into the planning process, we recommend that DOT SHOULD ENCOURAGE AN EXTENSIVE EDUCATIONAL PROGRAM COUPLED WITH CITIZEN DECISION-MAKING PARTICIPATION IN LAND USE AND TRANSPORTATION PLANNING. THIS PROGRAM SHOULD HAVE TWO FACETS: THE FIRST A BROAD APPROACH TO HOW LIFE STYLES ARE RELATED TO LAND USE AND TRANSPORTATION TO BE AIMED AT STUDENTS OF ALL LEVELS, THE SECOND A MORE SPECIFIC PROGRAM AIMED AT THE CITIZENS OF EACH COMMUNITY AND TIED IN WITH A COMMUNITY WIDE PLANNING PROCESS. Given the education citizens' groups must play an active role in the planning. We recommend that THE PARTICIPATION OF CITIZENS AND CITIZEN GROUPS BE ENCOURAGED AND SOLICITED AT THE OUTSET OF THE TRANSPORTATION PLANNING PROCESS AND CONTINUE IN AN ORGANIZED WAY THROUGHOUT THE PROCESS.

Given this citizen input, the Federal Highway Administration Division Engineer who is responsible for approving highway projects must use the data in making his decision. At present the Division Engineer must hold public hearings under the auspices of Policy and Procedure Memorandum, PPM 20-8, but he need not explain his approval or rejection of the project. To be sure that the community is heard we recommend that the FHWA DIVISION ENGINEER, IN PLANNING HIGHWAY ROUTES UNDER PPM 20-8, SUPPORT HIS DECISION GRANTING APPROVAL OF HIGHWAY PROJECTS WITH FINDINGS OF FACT CONCERNING LOCATION AND DESIGN ALTERNATIVES.

New Priority for Public Transit

While we have strongly recommended thorough studies to determine the needs for particular modes of transport in various locales, we now recognize the need for an emphasis on public transit. For too long, public transit has suffered from neglect. Local governments trying to make their transit systems pay for themselves, have found it necessary to continually cut back service and to raise prices to the point where it serves those people who **need** it the least. There is no rationale behind a self-supporting public transit system and we therefore, recommend that PUBLIC TRANSPORTATION IN THE CITY SHOULD BE REGARDED AS AN ESSENTIAL SERVICE, LIKE THE POLICE AND FIRE DEPARTMENTS. IT SHOULD NOT NECESSARILY BE REQUIRED TO BE SELF-SUPPORTING.

One of the guidelines for future action of the DOT's 1972 National Transportation Report Executive Summary is providing adequate transportation for disadvantaged citizens" [1, p. 25]. We wholeheartedly concur and further recommend that TRANSPORTATION IN AMERICA SHOULD BE READILY AVAILABLE NOT ONLY TO THE MIDDLE CLASS, WHICH IS ALREADY HIGHLY MOBILE, BUT ALSO TO THE SOCIALLY AND ECONOMICALLY DISADVANTAGED GROUPS IN THE CITY'S URBAN AREAS AND IN THE RURAL AREAS.

One of the problems of the "disadvantaged" is his lack of access to a place of employment. If his job is located within the city, public transit is often inadquate to get him to a potential job. But as more and more industry relocates to areas outside the city limits, the inner city poor find it even more difficult to reach a place of employment. Not only are peripheral areas inaccessible without a car, but even when public transit exists it is much too expensive. We therefore, recommend that TRANSPORTATION ACCESS FROM THE INNER CITY TO THE OUTER

METROPOLITAN AREAS—OUTBOUND TRANSIT COMMUTER SERVICE—BE IMPROVED.

The mode of transit which can best serve the immediate needs of most urban dwellers is the bus. It requires no new technology, nor any preparation of ways. It does, however, require new organizational procedures to make it serve more efficiently. Thus, we recommend that IMMEDIATE SHORT RANGE ACTION PROGRAMS BE INSTITUTED TO IMPROVE LOCAL BUS SYSTEMS. PRIMARY RESPONSIBILITY FOR THESE PROGRAMS REMAINS WITH LOCAL GOVERNMENT, BUT THE FEDERAL GOVERNMENT SHOULD PROVIDE INCENTIVE MONEY IN THE FORM OF MATCHING GRANTS—BOTH FOR CAPITAL IMPROVEMENTS AND OPERATING COSTS.

While we may provide adequate public transit in the future, we cannot assure ourselves that people will use it An educational program is necessary. In making a modal choice, the public is often concerned with cost. But many costs are hidden and public transit seems to be more expensive because "out of the pocket" costs are the only ones considered. Therefore, we recommend that DOT DESIGN AND ASSIST IN THE ADMINISTRATION OF AN EDUCATIONAL PROGRAM TO MAKE THE PUBLIC AWARE OF THE ACTUAL TOTAL COSTS ASSOCIATED WITH THE USE OF EACH MODE OF URBAN AND INTER-URBAN TRANSPORTATION. FOR THE PRIVATE AUTOMOBILE AND FOR EACH PUBLIC MODE, BOTH CAPITAL AND OPERATING COSTS SHOULD BE SPECIFIED. IN THE CASE OF THE PRIVATE AUTOMOBILE, DEPRECIATION, INTEREST, TAXES (ON THE VEHICLE AND THE GASOLINE IT USES), INSURANCE, AND PARKING SHOULD BE TAKEN INTO ACCOUNT. IN ALL CASES, THE CAPITAL AND MAINTENANCE COSTS OF THE RIGHT-OF-WAY, AS RELATED IN PASSENGER COSTS OVER A GIVEN TIME PERIOD ON LEVEL OF USAGE, SHOULD BE INCLUDED.

Software Before Hardware

In accordance with recommendation for improved bus service, we recommend THAT MORE ATTENTION BE GIVEN TO PROVIDING SHORT-TERM SOLUTIONS TO TRANSPORTATION PROBLEMS WITH THE USE OF AVAILABLE TECHNOLOGY. While we recognize the need for new devices to solve long-range planning problems, we have placed an emphasis on better organization and on more creative programs for the solutions of shorter range problems. For example, higher speed vehicles do not automatically decrease travel time since interface problems account for too great a loss of time.

The Urban Area Traffic Operations Improvement Program (TOPICS) encouraged such organizational devices for buses as preferential bus lanes, traffic control devices favoring buses and convenient parking near freeway bus stops. We applaud these measures and recommend that THE SOFTWARE FLEXIBILITY OF BUS SYSTEMS BE MORE EXTENSIVELY INVESTIGATED. PARTICULAR EMPHASIS SHOULD BE GIVEN TO MEETING PEAK PEOPLE MOVING DEMANDS DURING COMMUTER HOURS, AND IN ADDITION USING THE BUSES TO DELIVER FREIGHT AT OFF PEAK TIMES AND NIGHTS—SOME TRUCKING COMPANIES MIGHT BE INVOLVED IN SUCH AN EXPERIMENT. Further, to make buses useful to more users on a daily basis we recommend that BUS TRANSIT TICKETING BE POSSIBLE FOR A FIXED PERIOD OF TIME (E.G., 3 HOURS) SO THAT SHOPPERS COULD MAKE A NUMBER OF STOPS IN A RELATIVELY SHORT PERIOD OF TIME WITHOUT PAYING A NEW FARE EVERYTIME THEY REBOARD THE BUS.

Of course, one of the main purposes for recommending the extension of bus service is to provide a modal choice to traditional users of automobiles. We do, however, recognize the problem of convincing the motorist to leave his car at home, or at a convenient parking lot near a bus or train stop. Incentives, both positive and negative, should be considered to eliminate congestion in downtown urban areas. As one means of accomplishing this deterrent to automobile traffic, we recommend that LOCAL COMMUNITIES SHOULD CONSIDER EXERTING GREATER POLICY CONTROL OVER RESTRICTION OF STREET PARKING AS A COST-EFFECTIVE METHOD OF REDUCING CONGESTION. PRICING POLICIES SHOULD ENCOURAGE SHORT-TERM PARKING AND CAR POOLING INSTEAD OF LONG-TERM PARKING.

Perhaps, automobiles may be completely eliminated from downtown areas. Many European cities have experimented with this concept in certain areas of urban centers and American cities may profit from such a plan.

Thus, we recommend that DOT CONSIDER A DEMONSTRATION OF NO AUTO TRAFFIC IN SELECTED DOWNTOWN URBAN AREAS OR A PORTION THEREOF. FREEWAYS, ARTERIAL HIGHWAYS, AND STREETS WOULD ALL DEAD-END INTO PARKING FACILITIES WITH SIMPLIFIED DIRECT ACCESS TO DOWNTOWN AREAS VIA PUBLIC TRANSIT.

But the automobile itself is not the only culprit in the congestion problem. Other vehicles which travel more slowly such as trucks and construction equipment not only slow traffic down but also create frequent safety hazards. Thus, we recommend that STUDIES BE MADE OF THE EFFECT ON CONGESTION AND SAFETY OF SLOW VEHICLES DURING PEAK TRAFFIC PERIODS. IF THE EFFECTS ARE SIGNIFICANT, THE USE OF MAIN ROUTES BY THIS CLASS OF VEHICLES SHOULD BE CONTROLLED. The combination of these slower vehicles with numerous automobiles all arriving at a particular area at about the same time creates the well-known rush hour traffic jam. Here again new organizational concepts may help to ameliorate the situation. We therefore recommend that DOT INVESTIGATE THE FEASIBILITY OF LARGE SCALE DEMONSTRATIONS OF OTHER THAN THE CONVENTIONAL FIVE-DAY WORK WEEK AND THE STAGGERED WORK HOUR CONCEPT IN ORDER TO REDUCE CONGESTION AND AIR POLLUTION.

While congestion may be the major problem in urban transit, the interface problem, that which occurs when a passenger is changing modes or changing lines of the same mode, is very serious especially in inter-urban transit. When the time spent in getting to an airport and in waiting for a flight exceeds the time of the flight itself, something is wrong. We need new ways to solve this problem and we recommend the INITIATION OF IMMEDIATE RESEARCH ON NOVEL APPROACHES TO REDUCE PASSENGER CONGESTION AND INCONVENIENCE AT AIRPORTS. Airports, of course, also have a traffic problem above the ground. To help solve this problem we recommend INITIATION OF RESEARCH ON NOVEL APPROACHES TO THE SOLUTION OF AIR TRAFFIC CONGESTION. SUCH APPROACHES SHOULD UTILIZE NOVEL PUBLIC GROUND TRANSPORTATION CENTERS.

Human Factors

By far, the uniqueness of our report lies in its examination of human factors in the context of a transportation system. Those various human factors have been thoroughly described in Chapter II and need not be further elaborated here. We do recognize, however, that much research needs to be done in the areas of human factors and we recommend AN EXTENSION OF WORK IN PHYSICAL AND PSYCHOLOGICAL HUMAN FACTORS IN ALL FORMS OF PRESENT AND FUTURISTIC TRANSPORTATION AND MAN-MACHINE SYSTEMS.

But a mere extension of human factors research will not solve the problem. We must put this research to use in transportation systems. The role of transportation in our society must incorporate these human factors. Thus, we think that TRANSPORTATION SHOULD BE DESIGNED TO SERVE THE LARGER GOALS OF AMERICAN SOCIETY—TO PROVIDE ALL PEOPLE WITH A SYSTEM WHICH THEY CAN AFFORD AND WHICH WILL ALLOW THEM TO COMPLEMENT THEIR PRESENT EXPECTATIONS AND FULFILL THEIR BASIC HUMAN NEEDS.

We have previously recommended a new emphasis on public transit systems as a means to solving urban transportation problems. But public transit per se is not sufficient. This type of transit must be made to serve the public and often to encourage riders who normally use other modes. We find that SINCE THE PSYCHOLOGICAL BENEFITS OF A TRANSPORTATION SYSTEM, SUCH AS SELF-ESTEEM AND PERSONAL CONTROL, APPEAR TO BE FACTORS IN MODE CHOICE, TRANSIT DESIGNERS AND ADMINISTRATORS SHOULD ATTEMPT TO MAKE THE TRAVELLER ON PUBLIC TRANSPORTATION FEEL IMPORTANT AND SIGNIFICANT.

Our emphasis on the automobile has also created a serious problem for pedestrians. Often it is difficult, even impossible, to walk short distances since sidewalks are nonexistent or traffic is too dense. Thus, we recommend that for the future PEDESTRIAN MOVEMENT, AND PARTICULARLY THE REDUCTION OF CONFLICT BETWEEN PEDESTRIAN AND MOTOR VEHICLE MOVEMENTS, RECEIVE SIGNIFICANT CONSIDERATION IN URBAN TRAFFIC PLANNING AND OPERATION. While walking is a healthy exercise, so too is bicycling. The bicycle is becoming more and more popular, yet many cyclists find it necessary to drive to bicycle paths in order to ride. Therefore, we recommend that FOR EVERY MILE OF HIGHWAY

CONSTRUCTED A FIXED PERCENTAGE OF BICYCLE PATHS ALSO BE CONSTRUCTED. The Department of Transportation has been encouraging this practice; as have some states, such as Maryland. We applaud these projects and encourage more of the same.

Hopefully these new measures for pedestrians and cyclists will lead not only to a healthier community but also to a safer one. Safety is one of those human factors which cannot receive too much attention. Highway safety has been a great concern to our government, and the continued loss of 50,000 or more lives on American highways each year seems to dictate the need for whatever means necessary to lessen the number of fatalities. Experiments with air bags and other new technical devices may help but other, non-technical, concepts may also accomplish similar results. Thus, we recommend that NATIONAL STANDARDS FOR AUTOMOBILE DRIVER EXAMINATIONS BE ESTABLISHED WITH THE MANDATORY SATISFACTORY COMPLETION OF TRAINING COURSES. SUCH COURSES SHOULD INCLUDE, AS A MINIMUM, TRAINING IN ORDINARY URBAN AND FREEWAY DRIVING, ACCIDENT EVASION, AND CONTROL UNDER EMERGENCY CONDITIONS SUCH AS SKID AND TIRE FAILURES. RE-EXAMINATION SHOULD OCCUR PERIODICALLY ABOUT EVERY SEVEN YEARS, AND MORE OFTEN FOR DRIVERS IN HIGH ACCIDENT-RATE AGE GROUPS (e.g., 16-25 YEARS, 60-80 YEARS). In addition to these educational and testing procedures we also recommend that IN AUTOMOTIVE TRAVEL, THE USER POPULATION BE STUDIED UNDER ACTUAL OR SIMULATED DRIVING CONDITIONS IN ORDER TO IMPROVE VEHICULAR DESIGN, ESPECIALLY WITH RESPECT TO DEALING WITH EMERGENCY SITUATIONS. THIS ALSO SHOULD INCLUDE A STUDY OF PROBLEMS ASSOCIATED WITH GETTING OUT OF VEHICLES IN AN EMERGENCY. Furthermore, large numbers of automobile accidents involve camper type vehicles. Some guidelines concerning the structure of these vehicles must be initiated. Thus, we ask that DOT GREATLY STRENGTHEN REGULATIONS COVERING THE DESIGN OF CAMPER TYPE VEHICLES TO ENSURE STABILITY AND GOOD HANDLING QUALITIES.

While automobile safety is a major concern, there are other modes in which safety needs some attention. We should like to see continued work in the safety of all ground modes and we particularly want an EXTENSION OF WORK IN SAFETY OF AIR TRANSPORT, BOTH VEHICULAR SAFETY AND THAT ASSOCIATED WITH GROUND-TO-AIR COMMUNICATIONS. In addition we would like to see work on GUIDANCE, CONTROL AND COMMUNICATIONS SYSTEMS FOR SAFETY AND CONVENIENCE IN **ALL** TRANSPORTATION SYSTEMS.

Convenience, too, is one of the more important human factors. High steps on city buses are not only inconvenient but also hazardous. Work must be done in anthropometry so that these steps and numerous similar problems can be eliminated from the transportation system. Therefore, we recommend that SURVEYS OF THE USER POPULATION BE MADE TO DETERMINE REALISTIC ANTHROPOMETRIC DATA AND SPACE REQUIREMENTS. THESE SHOULD INCLUDE, WHEREVER POSSIBLE, DYNAMIC TESTS INVOLVING THE ACTUAL ENTRY INTO AND EXIT FROM VEHICLES. LUGGAGE HANDLING AND STORAGE SHOULD ALSO BE STUDIED. Inconvenient steps, entries and seating arrangements on transit vehicles are especially troublesome to handicapped persons. Here we are defining handicapped in a very broad sense. By handicapped we mean those with permanent or temporary physical disabilities as well as those who may be situationally handicapped by luggage, children, pregnancy. With this definition, we are speaking of about one-third of the transportation users. To make the transportation system work for these people we recommend that STUDIES OF THE HANDICAPPED AND THE ELDERLY BE MADE RELATIVE TO THEIR SPECIAL NEEDS AND THE POSSIBILITY OF MEETING THOSE NEEDS THROUGH IMPROVED VEHICLE AND FACILITY DESIGN BE INVESTIGATED.

Indeed, transportation is involved in our lives in countless ways. Even programs which are not specifically aimed at transportation affect transportation and most programs affect us in various ways. The human aspects of these programs must be foreseen and we recommend that COMPREHENSIVE IMPACT ASSESSMENTS BE REQUIRED OF ALL PROPOSED MAJOR GOVERNMENTAL PROGRAMS WHICH WILL HAVE A SIGNIFICANT IMPACT ON PEOPLE, LAND USES AND OTHER NATURAL RESOURCES TO ANTICIPATE POTENTIAL SOCIAL, ECONOMIC, TRANSPORTATION, ENVIRONMENTAL, AND SIMILAR PROBLEMS.

Environment

Of course, one aspect of human factors is concerned with the environment. Health problems attributable to air, water, and noise pollution are well known and transportation has contributed greatly to the degradation of the environment. Air pollution especially from the automobile, transportation noise pollution, visual pollution, and a general lack of land use policy are all aspects of transportation which affect us environmentally.

We see land use as the major environmental problem and the problem which has received the least attention. Recommendations concerning land use planning have been made in the section on **Goals and Policies** at the beginning of this chapter.

Air pollution, of course, is also a major problem with the automobile being responsible for over 60 percent of all air pollution. New emission controlling devices have ameliorated this problem in new cars but older cars still predominate on the road. But will the new devices which have been standard equipment function as well as expected? To assure the functioning of these devices, we recommend that EACH STATE FOLLOW THE LEAD OF STATES, SUCH AS NEW JERSEY, TO MEASURE EXHAUST EMISSIONS IN ALL CARS REGISTERED BY THE STATE AND TO REQUIRE OWNER MODIFICATION, AT THE MANUFACTURERS EXPENSE, OF THE VEHICLE TO MAKE IT MEET STANDARDS.

A more specific recommendation involving a simple technical device may also aid in reducing the amount of hydrocarbons released to the air. During a fillup at a gasoline station there are as many hydrocarbons released to the air as are released during twelve miles of driving. To remedy this situation, we recommend that SERVICE STATION GASOLINE HOSES BE CLOSED SYSTEMS WITH SNAP FITTINGS SUCH THAT NO AIR POLLUTANTS ARE RELEASED TO THE ATMOSPHERE DURING FILLUPS.

If air pollution has received a great deal of attention in the past few years, so too, has noise pollution. Intensive studies to determine the effects of noise from commercial aircraft on citizens who reside near airports have been undertaken and numerous recommendations designed to lessen this noise have been made. Truck noise, both from the engine and from the tires, has also been investigated but little has been done to implement the recommendations. In spite of the fact that the physiological, not to mention the psychological, effects of high noise levels have been rather well determined little has been done to punish the noisemaker or even to discourage him from making noise. We feel that harsh measures are necessary to quickly remedy the problem and, therefore, make the following two recommendations: (1) ENGAGING IN ACTIVITY ON PUBLIC PROPERTY WHICH CAUSES NOISE FROM A MECHANICAL SOURCE WITH INTENSITY GREATER THAN 70 DB(A) AT A DISTANCE OF 25 FEET REQUIRE A LICENSE FROM THE ENVIRONMENTAL PROTECTION AGENCY. (2) CAUSING NOISE FROM A MECHANICAL SOURCE, WITH INTENSITY GREATER THAN 55 DB(A) TO BE PROPAGATED ONTO PRIVATE RESIDENTIAL PROPERTY BE PROHIBITED.

Systems Approach

We have shown how transportation is so intimately involved with so many facets of our society. We have spoken of land use, pollution, human factors, economics, and politics. Other aspects such as urban form and energy use can easily be added to this listing. Such a complex problem as transportation must therefore be approached on a broad basis involving interdisciplinary teams of researchers who can use the systems approach to a solution of the problem. We, therefore, make the following two specific recommendations, hoping that combinations of these statements may also be regarded as worthy of implementation: (1) MULTI-DISCIPLINARY **SYSTEMS** STUDIES OF ENERGY SOURCES AND RELATIVE USES BY VARIOUS TRANSPORTATION SYSTEMS. (2) SYSTEMS STUDIES OF THE **NEEDS** FOR MOBILITY IN A CHANGING NATION AND THEIR IMPACT ON LAND USE (OR MISUSE) URBAN FORM AND INTERRELATED PATTERNS OF ECONOMIC ACTIVITY.

To aid in these interdisciplinary systems studies, there must be some kinds of predictive tools and models. Presently the Urban Mass Transit Administration (UMTA) and the Federal Highway Administration (FHWA) are providing some of these tools for use in transportation study and we recommend that UMTA AND FHWA CONTINUE AND IMPROVE THE PROGRAM TO PROVIDE RELIABLE PREDICTIVE MODELING TOOLS TO BE USED BY LOCAL PLANNERS. We also recommend that other modeling devices such as MODELS FOR HUMAN RESPONSE TO

VEHICLE RIDE CHARACTERISTICS BE DEVELOPED TO ESTABLISH FEASIBLE REGIONS OF NECESSITY, INDIFFERENCE, AND TOLERANCE IN ORDER TO EVALUATE TRADEOFFS IN ENGINEERING DESIGN.

Herein lies the rub. Human response is usually an unquantifiable input and the use of mathematical modeling devices to evaluate human response can present serious problems. The concept of cost benefit analysis from the area of economics and the concepts of systems analysis from engineering are often used to evaluate alternative proposals for transportation systems on the basis of mathematical models. The goodness of an alternative is judged by the numerical value of the resulting cost/benefit ratio or of some "performance' index. The validity of the results depend on the ability to quantify **all** pertinent parameters. This is beyond present capabilities for transportation systems. Therefore, although these methods may be helpful in comparing systems with small differences, they are not to be trusted as substantial evaluations of major programs unless the non-quantifiable system parameters have been constrained to lie within limits set by policy. For instance—a cost-benefit analysis concept for evaluation in such areas as crash injury, or mobility for the handicapped, cannot be done. The economic value of lives lost in auto accidents or of a person confined to a wheel chair being able to take a bus is not a sufficient basis in modern America. We must stop placing monetary values on human life and injury and we recommend THE ADOPTION OF A POLICY FOR TRANSPORTATION PLANNERS AND DESIGNERS TO CEASE MAKING AN ECONOMIC COST-BENEFIT ANALYSIS WHEN NON-QUANTIFIABLE FACTORS ARE INVOLVED.

New Technology

While we have emphasized better organization and more creative programs (i.e., software) for the solutions of shorter range transportation problems, we do recognize the need for new devices to solve long range planning problems. These new devices should, however, be developed in line with our recommendations on land use, pollution, energy sources and urban form.

Again land use planning has been neglected in the past. Buying land to hold new highways or rights-of-way for rail transit must be limited to those times when it is absolutely necessary. What we need, in terms of new technology, are new modes which required little or no land for the construction of transportation systems. To this end, we recommend that IN VIEW OF URBAN LAND COSTS AND ENVIRONMENTAL DEGRADATION INHERENT IN LAND BASED TRANSPORTATION SYSTEMS, COORDINATION OF THE DEVELOPMENTAL WORK ON AN INTEGRATED TUNNELLING SYSTEM CAPABLE OF PRODUCING TRANSPORTATION TUNNELS AT ACCEPTABLE RATES AND COSTS.

In the area of energy consumption, there is dire need for careful planning of transport systems. Transportation presently consumes about 20 per cent of all the energy in the United States and it is estimated that this figure will rise to 25 per cent by the year 2000. To avoid any continuation of this transportation-energy spiral, indeed, to create a downward trend in energy consumption, RESEARCH INTO NEW POWER AND LOCOMOTION SYSTEM CONCEPTS FOR **ALL** VEHICULAR SYSTEMS WITH GOALS OF REDUCTION OF ENERGY CONSUMPTION, NOISE VIBRATION, AND POLLUTION.

This recommendation suggests, energy consumption cannot really be divorced from noise and other forms of pollution. We applaud the continuation of efforts to reduce air pollution from transportation modes and in the area of noise abatement we recommend that an EXTENSION OF WORK IN QUIET ENGINES FOR AIRCRAFT AND IN SIMILAR ENGINES WHICH MIGHT BE USED ON SUCH LAND-BASED TRANSPORTATION SYSTEMS AS TRACKED-AIR-CUSHION-VEHICLES (TACV).

Safety on the highway must also be improved. Current research on technical devices is to be encouraged but we also need ADDITIONAL RESEARCH BE INITIATED ON ALTERNATE INTERNAL WAYS OF DISPLAYING AN EMERGENCY MESSAGE OR SIGNAL TO VEHICLE DRIVERS. EXTERNAL ACOUSTIC WARNING DEVICES ARE BECOMING LESS ADEQUATE AS SPEEDS, HIGHWAY NOISE, VEHICLE ACOUSTIC INSULATION, AND AIR CONDITIONING INCREASE. IN ADDITION TO WARNINGS OF EMERGENCY VEHICLES, THESE DISPLAYS MIGHT NOTIFY DRIVERS OF PROPER LANES FOR FREEWAY EXITS AND DANGEROUS SITUATIONS SUCH AS IMPENDING FOG OR ICY ROADWAYS.

Aeronautical research over the past few decades has provided us with much in-

formation which can be applied to other modes of transportation. Speed is important for ground modes and we recommend RESEARCH ON VERY HIGH SPEED (SEVERAL HUNDRED MPH) LAND BASED TRANSPORTATION SYSTEMS UTILIZING APPLICATIONS OF CURRENT AERONAUTICAL RESEARCH AND TEST FACILITIES. In addition to speed, we need flexibility and here we recommend that an air mode be encouraged; thus we want an EXTENSION OF WORK ON V/STOL DEVELOPMENT AND CERTIFICATION.

Finally, no simple technical device can even make a dent on the problem. These devices must be incorporated with human factors data and modelling so that overall solutions can be reached. We therefore, recommend that PROJECTS WHICH INVOLVE ADVANCED TECHNOLOGICAL CONCEPTS, BE FUNDED, BUT THAT THESE PROJECTS BE BROADENED TO INCLUDE EXTENSIVE PRE PROJECT AND POST PROJECT ATTITUDE AND USER DATA. THESE ENDEAVORS SHOULD BE STRUCTURED TO PROVIDE MODEL INFORMATION USEFUL TO THE URBAN PLANNER ATTEMPTING TO PREDICT USER ACCEPTANCE OF NEW MODES. An example of this type of project is the demonstration at Morgantown, West Virginia, sponsored by UMTA. We want to see more of this kind of project and similar ones in cities such as Washington, D.C., which is presently undertaking major changes in transportation.

EPILOGUE

"For my part, I travel not to go anywhere, but to go...the great affair is to move."

Robert Louis Stevenson. *Travels with a Donkey* 1878

Recently, the great American love affair between man and automobile has been showing signs of strain. Divorce, while not imminent, is being whispered about in some circles.

We feel that less radical solutions are possible. There is no question, however, that significant problems exist. People's homes are displaced by freeways, neighborhoods are fractured by highways that cut through playgrounds and parks, and the air of cities is fouled by exhaust fumes. At the same time, traffic congestion makes real mobility a fantasy. All are symptoms of the extreme lack of co-ordination between transportation and overall urban and regional planning. The failure to consider the real needs of people—housing needs, work needs, recreational needs, needs for goods and services—have led to today's imbalance between public and private transportation.

In our society, horizontal mobility is often a prerequisite for vertical mobility. The urban and rural poor are often cut off from work and training opportunities because they lack the means to get there. Thus, the extreme reliance on the automobile at the expense of public transportation tends to perpetuate poverty by denying the poor true equality of opportunity. Indeed, the poor are not the only segment of our society who are immobile because of a lack of access to the private automobile. The young, the aged, and the handicapped also suffer the penalties of immobility.

The solution does not lie in a ban on highways or automobiles. Instead, there must be recognition of the need for more balance in our transportation planning, in order to improve the quality of life for all our citizens. Congress has promised to appropriate twelve billion dollars over the next ten years for public transportation in the city. While this is a start, it is only a fraction of the federal money that will be spent on highways over the same period. Clearly, a firmer commitment to public transportation is needed.

The success of the metroliner between Washington and New York indicates that inter-urban rail service which is comfortable, convenient, fast, and which caters to the needs of the passenger can successfully compete with the automobile (and even the airplane over moderate distances). We believe that such an approach can succeed within a city as well.

Our findings indicate that technology is not as important as co-ordinated organization, and that hardware is secondary to comprehensive planning and a change in our goals and priorities, from the local to the national level. Robert Louis Stevenson to the contrary, transportation in itself is not an intrinsic good. Nevertheless, adequately planned and organized public transportation can point the way to a better life for all Americans. We strongly urge adoption of this ideal as a national goal.

APPENDICES

A. Participants and Secretarial Staff. NASA-ASEE Engineering Systems Design Program. 1972

B. Acknowledgements

C Visiting Lecturers and Consultants

D Protection of the Environment

E Block Diagrams—An Overview

F Human Response to Acceleration and Vibration

G Selecting Urban Transportation Modes

H Torpor and Temper on West Ocean View Avenue

I. Organizational Structure of the U.S Department of Transportation

J. Group Organization

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APPENDIX A

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NASA-ASEE ENGINEERING SYSTEMS DESIGN PROGRAM

SUMMER 1972

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APPENDIX C

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NASA-ASEE ENGINEERING SYSTEMS DESIGN

Date	Speaker/Affiliation/Topic
June 12, 14	DR RANDALL M. CHAMBERS Technical Advisor for Systems Design Team, NASA Introduction to Human Factors Engineering
June 13	DR DWIGHT M. BAUMANN Carnegie-Mellon University Interdisciplinary Design in Transportation Systems
June 15	DR. CARL F. ZOROWSKI North Carolina State University Methods of Systems Design for Societal Problems
June 16	DR. WALTON L. JONES Deputy Director of Life Sciences, NASA Headquarters, Washington Recent NASA Human Factors Research
June 19	DR. HAROLD VON BECKH Director Crew Systems Department, U S Naval Air Development Crew Safety in Severe "G" Environments
June 20	DR. WARD EDWARDS Associate Director, Highway Safety Research Institute, University of Michigan Theory for Evaluation of Transportation Systems
June 21	DR. GORDON P. FISHER Civil & Environmental Engineering, Cornell University Fundamentals of Transportation
June 26	DR. ALBERT ZAVALA Head Life Sciences, Cornell Aeronautical Laboratory Current Human Factors Research in Transportation
June 27	DR. RICHARD W. GRIFFIN Department of Political Science, Georgia Institute of Technology Decisions in the Political Scene
June 28	DR. CHARLES Y WARNER Director, Office of Crashworthiness, National Highway Transport Safety Administration, Department of Transportation Crash Protection Systems Research
June 29	DR FRANK SUTTON Dean of Engineering, University of Wyoming Human Tolerances on Public Transportation Systems
July 5	MR. HARVEY HAACK Chief Planning Engineer, Chicago Area Transportation Study (CATS) Long Range Planning for all Transportation Modes in the City of Chicago
July 7	DR DONALD B. DEVOE Department of Transportation Human Factors in Railroads
July 11	DR. HERBERT J. BAUER General Motors Corporation, Transportation Research Department Transportation Research

July 12	AXEL T MATTSON Assistant Director, Office of the Director for Center Development and External Affairs—NASA Langley Transportation Overview—NASA Role
July 13	DR TUNG AU Professor of Civil Engineering, Carnegie-Mellon University Systems Analysis and Design Processes
July 13	MR. GARY KRAUS S E. Michigan Council of Governments (COG) Transportation and Urban Planning· The COG Concept
July 14	MR. JOHN BURBY Associate Editor, *National Journal* Comprehensive Planning in Transportation Planning
July 17	DR CARL SWERDLOFF Chief, Inter-City Transportation Branch, Department of Transportation Governmental Coordination in Transportation Planning
July 18	WILLIAM CONNER NASA Langley Research Center Status of V/STOL Aircraft Development
July 21	COL CHARLES R FOSTER Department of Transportation Noise Factors in Transportation Systems and their Abatement Potential
July 26	DR. IRA D. JACOBSON University of Michigan Demand Modelling for Travel Modes
July 28	DR. FRANK D HART North Carolina State University Transportation Noise An Overview
July 31	DR. DONALD G. MORIN Federal Railroad Administration, Department of Transportation Advanced Concept Ground Transportation Systems—Research, Development and Demonstration
August 14	DR. JOEL SNOW Deputy Assistant Director for Science and Technology, National Science Foundation Research Applied to National Needs (RANN)

APPENDIX D

LEGISLATIVE AND ADMINISTRATIVE PROTECTION FOR THE ENVIRONMENT

1. Highway Construction

Section 128 and Public Policy and Procedure Memorandum 20-8 The Dual Public Hearing Requirement

Title 23 of the United States Code contains the federal-aid highway legislation The provisions of 23 U S C 128 have required public hearings to allow for citizen participation in the route selection process However, the Federal Aid Highway Act of 1968 included amendments which specifically required the public hearings to consider the urban and social impact of the highway project

> Any state highway department which submits plans for a Federal-aid highway project involving the bypassing of, or going through, any city, town, or village, either incorporated or unincorporated, shall certify to the Secretary that it has had public hearings, or has afforded the opportunity for such hearings and has considered the economic and social effects of such location, its impact on the environment, and its consistency with the goals and objectives of such urban planning as has been promulgated by the community [1]

The requirements of section 128 are implemented by Policy and Procedure Memorandum (PPM) 20-8, used by the Federal Highway Administration on January 14, 1969 PPM 20-8 requires a dual public hearing procedure as a prerequisite to approval of Federal-aid highway projects The "corridor public hearing" is held before route location is approved, while the "highway design public hearing" considers the environmental effects of a specific design proposal. PPM 20-8 (3) lists 23 "social, economic, and environmental effects" to be considered at the public hearings as being relevant to highway location and construction Significantly, PPM 20-8 also requires state highway departments to establish and maintain a list upon which any federal agency or local interest group may enroll to receive notice of highway projects in any area specified by that particular organization [2]. And finally, a request for approval of a project proposal with respect to location or design shall include an analysis of information gathered in connection with the public hearings, and also consideration of information submitted by interest groups [3].

2. Section 138 and Section 4 (f) Public Parklands

Current Congressional Legislation embodies policies relating to the use of remaining open land and for parklands as well as highway construction In 1966, the Bureau of Public Roads, then located in the Department of Commerce administered the provisions of Title 23 As was the case in 1966, highway legislation and appropriations are controlled by the Public Works Committees of the Senate and House Amendments to the 1966 federal-aid highway legislation provided the initial federal protection for the environment in Section 138 by declaring a "maximum effort to preserve parklands and historic sites" [4] Approval of the use of parkland or historic sites was limited "unless such program included all possible planning, including consideration of alternatives to the use of such land, to minimize any harm to such park or site resulting from such use [5]

Congress also passed the Department of Transportation Act in 1966, which included more restrictive language relating to the use of public parklands for any transportation project in Section 4 (f)

> The Secretary shall cooperate and consult with the Secretaries of the Interior, Housing and Urban Development, and Agriculture, and with the States in developing transportation plans and programs that include measures to maintain or enhance the natural beauty of the lands traversed After the effective date of this Act, the Secretary shall not approve any program or project which requires the use of any land from a public park, recreation area, wildlife and waterfowl refuge, or historic site unless (1) there is no feasible and prudent alternative to the use of such land, and (2) such program includes all possible planning to minimize harm to such park, recreational area, wildlife and waterfowl refuge, or historic site resulting from such use [6]

With the establishment of the Department of Transportation (DOT), the Bureau of Public Roads was absorbed within the DOT as the newly created Federal Highway Administration (FHWA) It is to be noted that the strict requirements of Section 4 (f) applied to all project proposals within the DOT as distinguished from the limited application of Section 138 of the Federal-aid Highway Act of 1966 It became necessary to resolve the obvious conflict of the legislative provisions with regard to the highway program The opposition and lack of concern for environmental consequences of the state highway departments were expressed during hearings on the Federal-aid Highway Act of 1968 by testimony of the American Association of State Highway Officials

> At the risk of being charged as insensitive to recreation, conservation and historical sites, we believe there is an overemphasis and overenthusiasm in administering Section 4 (f) of the Transportation Act of 1966, to the point that needed highway improvements are being delayed and complicated, and that Section 4 (f) is being used to reopen decisions previously made or slow down the program .

The legislative history of Section 136 of the 1968 Federal-aid Highway Act reflects the crucial difference of interpretation of the two provisions applicable to the highway program The Committee on Public Works of the House recommended striking the provision that approval of the Secretary of Transportation of projects must be based on a finding of no feasible and prudent alternatives in addition to all possible planning to minimize harm, and rather to substitute the single ineffectual requirement that

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1 23 U S.C §128 (a) (Supp. V, 1970)

2. PPM 20-8 (5)

3 PPM 20-8 (9), (10).

4. Federal-Aid Highway Act of 1966, §15, 80 Stat 771.

5. Ibid

6. Department of Transportation Act §4 (f), 80 Stat. 934, 1966.

a project include "all possible planning " The House adopted the recommendation of the committee However, the Senate Committee on Public Works urged retention of the more restrictive language of Section 4 (f) Subsequently, a conference committee amended both sections to make them identical and more nearly like the original Section 4 (f), representing a victory for the Senate conferees

> After the effective date of the Federal-Aid Highway Act of 1968, the Secretary shall not approve any program or project which requires the use of any publicly owned land from a public park, recreation area, or wildlife and waterfowl refuge of national, State or local significance as determined by the Federal, State, or local officials having jurisdiction thereof, or any land from an historic site of national, State or local significance as so determined by such officials unless (1) there is no feasible and prudent alternative to the use of such land, and (2) such programs include all possible planning to minimize harm to such park, recreational area, wildlife and waterfowl refuge, or historic site resulting from such use [7]

The amendment of both sections of law to require that there be no "feasible" alternative route admits little administrative discretion to be allowed the Secretary of Transportation The Senate interpretation of Section 138 is indicated by a statement of Senator John Sherman Cooper of Kentucky

> The language prohibits any intrusion upon or invasion of these lands or areas if one of these bodies finds it is of National, State, or local significance, and the highway cannot be built, unless there is no feasible and prudent alternative to doing so [8].

In fact, the Supreme Court cited the need for a critical review by DOT of Section 4 (f) cases in *Citizens to Preserve Overton Park v Volpe* (1971) [9] Judicial opinion prescribed that economic cost factors and disruption of the community considerations were **not** intended to be assessed on an equal basis with the preservation of parkland. The Court required a substantial inquiry to serve the paramount importance of the statute--the protection of parkland.

Thus, Congress intended by Section 138 of the Federal-aid Highway Act of 1968 that the protection of parkland was to be given paramount importance and that the Secretary of Transportation was not to approve the destruction of parkland unless he determined that the alternative routes presented unique problems. The determinations of the Secretary are subject to judicial review under the Administrative Procedure Act to decide whether the Secretary acted within the scope of his authority, or if the decision was arbitrary, an abuse of discretion, or otherwise not in accordance with law

Section 106—The National Historic Preservation Act of 1966

The National Historic Preservation Act of 1966 provides for the maintenance of a National Register of "districts, sites, building, structures, and objects significant in American history, architecture, archeology, and culture [10] Section 106 of the Act provides protection for historical sites from Federal projects

> The head of any Federal agency having direct or indirect jurisdiction over a proposed Federal or federally assisted undertaking in any State and the head of any Federal department or independent agency having authority to license any undertaking shall, prior to the approval of the expenditure of any Federal funds on the undertaking or prior to the issuance of any license, as the case may be, take into account the effect of the undertaking on any district, site, building, structure, or object that is included in the National Register. The head of any such Federal agency shall afford the Advisory Council on Historic Preservation established under title II of this Act a reasonable opportunity to comment with regard to such undertaking [11].

The provisions of the Act thus complement the mandate of Section 4 (f) that the Secretary of Transportation make a "special effort . . to preserve historic sites" and that approval of a project which requires the use of land from an historical site is not to be given unless (a) there is no reasonable alternative, and (b) all possible planning to minimize harm to the histor site is included [12].

3. Legislative and Administrative Protection for the Environment From Airport Location

The Airports and Airway Development Act of 1970 provides significant protection for the environment from the adverse effects of aviation expansion and improvement. The declaration of national policy requires "that airport development projects authorized pursuant to this subchapter shall provide for the protection and enhancement of the natural resources and the quality of environment of the Nation." The Secretary of Transportation is required to consult with local, State, and Federal agencies to insure the conservation of national resources and the preservation of environmental quality Approval of an airport project that will have an adverse effect on "fish and wildlife, natural, scenic and recreation assets, water and air quality," and other natural resources may not be authorized by the Secretary unless the Secretary certifies in writing as a matter of public record that no feasible and prudent alternative exists to the proposed project and that all possible steps have been taken to minimize adverse effects on the environment [13].

Approval of project applications for airport development is also contingent upon whether "fair consideration has been given to the interest of communities in or near which the project may be located" [14] In implementing the policy objective of protection for natural resources, the Secretary of Transportation is required to specifically consult with the Secretaries of the Interior and of Health, Education, and Welfare [15].

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7 Federal-Aid Highway Act of 1968 §18, 82 Stat. 823-24, 23 U.S.C. §138 (Supp V. 1970); 49 U.S.C. §1653 (f), (Supp V, 1970).

8 114 Cong. RFC. 24033 (1968).

9. *Citizens to Preserve Overton Park* 401 U.S. 402 (1971).

10. 16 U.S.C. §470 (a) (1)

11. 16 U.S.C. §470 (Supp V, 1970).

12. 49 U.S.C. §1653 (f) (Supp V, 1970)

13. 49 U.S.C. (Chapter 25) §1716 (c) (4).

14. Pub L 91-258, May 21, 1970, 84 Stat. 219, §1716 (c) (3).

15. §1716 (c) (4)

The Secretary of Transportation thus may authorize a project that requires the use of publicly owned land from a park, recreation area, or wildlife and waterfowl refuge if it is determined there exists no feasible and prudent alternative to the use of such land and that the proposal includes all possible planning to minimize harm to the areas affected. The provisions of Section 1723 apply to the requests for use of land owned or controlled by the United States and reasonably necessary for carrying out a project for airport development. The Secretary is required to file a request with the head of the department or agency having control of the land—to convey the necessary lands to the public agency sponsoring the airport development project [16]. However, the provisions are non-applicable with regard to certain exempt lands, which may not be used for airports, within a national park or a national monument under the administration of the National Park Service; or within any unit of the National Wildlife Refuge System under the jurisdiction of the Bureau of Sport Fisheries and Wildlife, or within any national forest or indian reservation [17].

Before approval of any project proposal is authorized by the Secretary, the sponsoring agency is required to have held public hearings for considering the environmental effects of the project on the surrounding community and to determine "its consistency with the goals and objectives of such urban planning as has been carried out by the community" [18]. Additionally, to enable the Secretary to approve a project application, the governor of the state, or under certain circumstances, a federal official, must certify in writing that "there is a reasonable assurance that the project will be located, designed, constructed, and operated so as to comply with applicable air and water quality standards" [19].

Further procedural requirements are intended to provide adequate consideration for the adverse environmental effects of airport location. The Federal Aviation Administration (FAA) regulations stipulate:

> In particular alternative actions that will minimize adverse impact are to be explored and both the long and short range implications to man, his physical and social surroundings, and to nature, should be evaluated in order to avoid to the fullest extent practicable undesirable consequences for the environment.

And finally, an environmental impact statement prepared in accord with Section 102 (2) (c) of the National Environmental Protection Agency must be submitted to the President's Council on Environmental Quality and made available to the public.

In the area of the control and abatement of aircraft-engine noise, the FAA has established rules for allowable engine noise levels as part of criteria for aircraft type certification. The allowable noise levels vary with aircraft size and type and for different aircraft operations. The rules issued December 1, 1969, prescribed noise levels on approach ranging between 102 and 108 ENDdB, while during takeoff, allowable noise limits varied between 93 and 108 EPNdB. Sideline noise along the runway during idling or taxiing was limited to a range between 102 and 108 EPNdB [20]. Additionally, the FAA has implemented a dual effect control program to reduce the level of aircraft-engine noise in the vicinity of airports serving jet aircraft. First, air traffic controllers are to delay the final landing descent of turbojets until these aircraft are relatively close to their destination airport. And secondly, jet pilots taking off are to be instructed to climb out rapidly [21]. With regard to the control of aircraft air pollution agreements between the FAA and the airline industry have provided for the retrofit of smoke-reducing combustors to reduce the level of visible pollutants emitted by jet engines [22].

The Clean Air Acts

The Clean Air Act (1970) as amended, charges the administrator of the EPA with major responsibilities for the control of motor vehicle emissions. These duties include establishing emission standards for pollutants which endanger public health and welfare, administrating a number of related activities concerned with vehicle testing, certification and enforcement, regulating the content of fuel; demonstrating the feasibility of low emission vehicles; monitoring the development of improved devices to control emissions from internal combustion engines, and directing research and development activities related to alternative power systems. In addition, Section 202 (b) (1) (A) and 202 (b) (1) (B) require that (1) The 1975 automobiles must achieve a 90% reduction in the emissions of hydrocarbons (HC) and in carbon monoxide (CO) which were allowable in 1970, (2) The 1976 automobile must achieve a 90% reduction in the emissions of oxides of nitrogen (NOx) from the average levels measured on 1971 automobiles which were not subjected to any federal or state NOx emissions standards.

History of State and Federal Standards

In 1959, the State of California initiated the control of motor vehicle emissions with the adoption of standards to control exhaust hydrocarbons and carbon monoxide. In 1960 the standards were supplemented with standards to control emissions resulting from crank case blowby. California required a first level of crank case emission control effective with the 1963 models, improved crank case emission control for 1964, and control of exhaust hydrocarbons and carbon monoxide in 1966.

In 1965 amendements to the Federal Clean Air Act gave the Secretary of the Department of Health, Education and Welfare, the authority to control emissions from motor vehicles. Accordingly, on March 30, 1966, the initial Federal motor vehicle emissions standards were adopted to become applicable with the 1968 models. These standards and procedures required some control of exhaust hydrocarbons and carbon monoxide from light duty vehicles and 100% control of crank case emissions from gasoline fueled cars, busses, and trucks.

In June, 1968, revised Federal standards were published which required more stringent control of hydrocarbons and carbon monoxide from light duty vehicles, of evaporative emissions from the fuel tanks and carburetors of light duty vehicles, of exhaust hydrocarbon and carbon monoxide emissions from gasoline fueled engines for heavy-duty vehicles, and of smoke emissions for diesel engines for heavy-duty vehicles. The evaporative emissions standards became fully effective with model year 1970. The other standards applied to 1970 model year vehicles and engines. With the introduction of the 1970 models, the automotive industry had reduced

16. §1723 (b)
17. §1723 (c)
18. §1716 (d) (1).
19. §1716 (e) (1).
20. DOT 4th Annual Report
21. DOT 5th Annual Report
22. DOT 4th Annual Report

hydrocarbon emissions by almost 75%, carbon monoxide emissions by about 33%

On November 10, 1970, standards were published applicable to 1972 model light- and heavy-duty vehicles and heavy-duty engines The significant modification in these conditions pertaining to the method of evaulating the exhaust hydrocarbon and carbon monoxide emissions from light-duty vehicles

On January 30, 1971, the Environmental Protection Agency (EPA) published an advanced notice of proposed rule-making concerning its intention to (1) promulgate control prohibitions on the addition of alkyl gasoline fuels from motor vehicles at the earliest possible date They stated that systems design to control NOx emissions to meet standards applicable to 1973 model year cars may require that low lead gasoline be generally available in late 1972, and the probable use of catalytic converters to achieve the 1975 Hydrocarbons-Carbon monoxide standard makes it imperative that unleaded gasoline be generally available at that time At this time they also requested that the tax on lead and gasoline be implemented so that unleaded gasoline would be competitively priced On February 26, 1971, all domestic and foreign auto manufacturers were requested by the EPA to furnish EPA with the necessary economic and engineering data required to make their vehicles meet the standards promulgated by the EPA. On April 7, 1971, a notice of proposed rule-making was published concerning the requirement for the preparation of state implementation plans On April 10, 1971, the federal certification test results for 1971 model year motor vehicles and engines were published On April 30, 1971, National Primary and Secondary Ambient Air Quality Standards were published as final rule-making, including standards for hydro-carbons, carbon monoxide, and oxides of nitrogen Table 1 shows the air quality standards and the reference measurement technique used to obtain these measurements

There seems to be considerable controversy over the air quality standards and how they relate to urban environments for the 1975-7 deadlines Specialists from Federal Agencies reported to the White House in March 1972 that National Air Quality Standards mandated by Congress cannot be met in many urban regions They said this prediction would hold true even if prescribed automotive emissions standards can be met They described air pollution as a regional problem and reported that (1) in many regions of the country the attainment of desirable air quality will depend on control of stationary sources as much or more than it depends on the control of automotive sources, (2) the national ambient air quality standards are unattainable in many urban air quality regions in the 1975-77 time period even with the imposition of such controls, and (3) the feasibility of achieving mass-produced gasoline powered automobiles that will meet the 1976 emissions standards is questionable If these levels can be achieved, substantial additional costs will be involved for initial equipment, maintenance and increased fuel comsumption The complex automotive emission inspection program called for by the provisions of the Clean Air Act will not insure that the low emission levels demanded will be maintained during owner operation of these vehicles

These Federal agencies specialists also warn that regulation in the air pollution area "should not be based upon a blind faith in technology" or a presumption that major breakthroughs are available if enough money is spent

The advisors to the National Academy of Sciences believe that it is still possible for larger auto manufacturers to produce 1975 model year vehicles that will meet Congressionally established emissions standards However, they suggested "interim" standards if the EPA agreed to the auto industry request for a one-year suspension However, the EPA administrator, W.D. Ruckelshaus, decided not to grant a one-year delay to the auto industry group Ruckelshaus based his decision largely on the finding that catalysts are both "safe and highly effective" in reducing emissions He urged auto firms to act quickly to make their commitments to catalyst suppliers The Ruckelshaus decision, which most industry officials expected to provide them with an additional year for more research and testing, has greatly complicated the problem of compliance with the automobile emissions standards

TABLE D.1
NATIONAL AIR QUALITY STANDARDS FOR AUTOMOTIVE-RELATED POLLUTANTS AND THE CORRESPONDING REFERENCE ANALYTICAL METHODS

Pollutant	Air quality standard[1]	Reference method
Carbon monoxide	9 ppm for 8 hr[2] 35 ppm for 1 hr[2]	Nondispersive infrared spectroscopy.
Nonmethane hydrocarbons	0.24 ppm C for 3 hr[2] (6 to 9 A.M.)	Total HC by flame ionization, methane by gas chromatography, nonmethane HC by difference
Nitrogen dioxide	0.05 ppm—annual arithmetic mean	Jacobs-Hochheiser
Photochemical oxidant	0.08 ppm for 1 hr[2]	Chemiluminescent spectroscopy

[1] Primary (health) and secondary (welfare) standards are equal for these four pollutants.

[2] Maximum concentration, not to be exceeded more than once per year.

Ruckelshaus declared that "although auto manufacturers demonstrated difficulties in their efforts to reduce exhaust pollutants, they have not established such a technology does not exist Impressive progress has been achieved in controlling auto emissions by a variety of control systems employing catalysts. An analysis of all data suggests that technology may well be applicable for the 1975 cars to meet these standards

The EPA has recently, June 1972, come under criticism by the Comptroller General of the U.S due to its limited progress in controlling air pollution from autos due to lack of authority, management ability, and funds A highly critical report to Congress from the (watchdog) agency details many weaknesses in EPA's efforts to assert control over auto emissions and to develop new low polluting engines.

Auto Industry Concerns

Various auto industry representatives have expressed a number of concerns about the prospect of meeting the 1975 and 1976 standards It has been asserted that the proposed standards cannot be attained with available technology, would be far too expensive compared to the effectiveness of air quality and included deadlines and does not provide the industry with sufficient lead time In addition, some manufacturers have also expressed concern for increases in costs and reductions in fuel economy and in driveability after modification to meet the 1975-76 standards

These manufacturers have pointed out that the law requires them to solve two very different technical problems almost simultaneously In order to meet the 1975 standards on hydrocarbon and carbon monoxide controls more complete combustion in an oxidation atmosphere must be obtained while controlling oxides of nitrogen necessitates lower combustion temperatures and/or a reduction atmosphere to convert these emissions to nitrogren and oxygen gases. The 1975 NOx standards have been labeled by various domestic and foreign auto producers as requiring technology beyond the existing state of the art.

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APPENDIX E

BLOCK DIAGRAMS — AN OVERVIEW

Basically block diagrams are drawn to identify and/or trace causes, effects, and systems. It is logical therefore, that the diagram elements are composed of causes, effects, and algebraic operations. As an example, Figure E.1 shows a typical diagram. The elements in the figure will be discussed first.

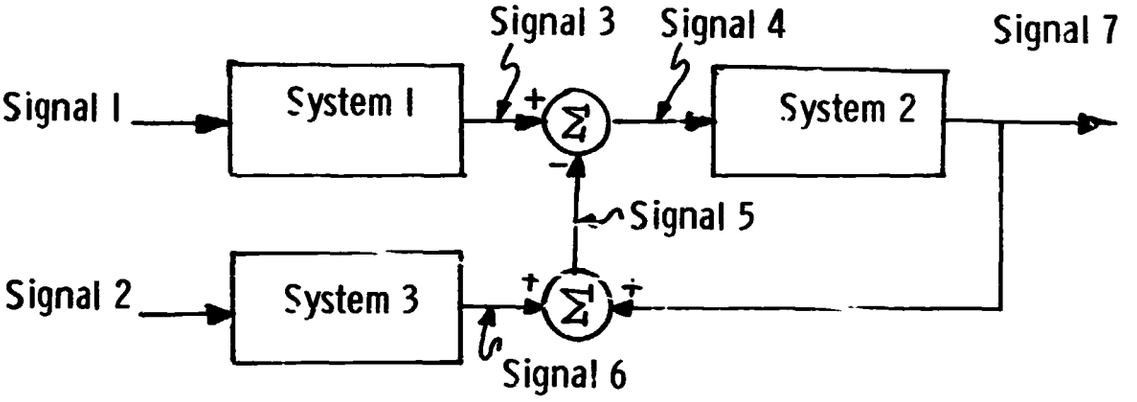


FIGURE E.1
A BLOCK DIAGRAM TO TALK ABOUT

I. Signals

Signals are the basic entities being sent around; they constitute whatever is processed, changed, or transformed by the operations indicated in the circles and rectangles. Therefore, the causes (or inputs) to systems are, in fact, signals. In addition, the effects (or outputs) are considered to be signals. Very often the output of one system must later serve as the input to another system.

Diagrammatic Representation

Signals are represented by **directed** arrows. The directed arrow implies that the signal can only travel in one direction. Figure E.2 illustrates examples of signals.

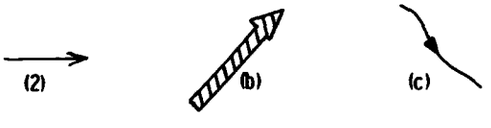


FIGURE E.2
EXAMPLES OF SIGNALS; ALL ARE EQUIVALENT

Signals may be labelled according to the functions or entities represented by them. Labelling may appear at any convenient location along the arrow.

FIGURE E.3
LABELLED SIGNALS

Consistency Conditions

a. **Physical Size:** Physical size or shape has no bearing upon signal characteristics. (Sometimes, double-walled arrows (Figure 2b) are used to denote many variabled signals.)

b. **Equal Potential:** All points along the same arrow (regardless of shape or size) have the same label and the same quality, polarity, and quantity.

c. **Polarity:** Signals can have polarity; that is, they can be positive or negative.

The careful observer will at this point question the meaning of **directed** arrows since it appears to conflict with polarity. We resolve part of the difficulties by observing that polarity is the answer to the question, "Is the signal greater than zero or less than zero?" In most cases zero is an arbitrarily assigned reference point that is placed at a location on a continuum of values. This is usually true of such variables as voltage and information. On the other hand, when flow variables switch in polarity from positive to negative, their direction of movement changes. In this case, one uses both sense and polarity to ascertain the true direction of flow. Thus, all diagrams in Figure E.4 have exactly the same meaning.

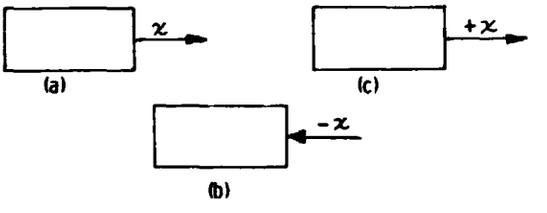


FIGURE E.4
POLARITY AND ALGEBRAIC LOGIC

II. Systems

Systems offer the only legitimate way of transforming one signal into another. Thus, systems are placed to denote the location of all transformations or signal changes.

Diagrammatic Representation

Systems are represented by closed figures (usually rectangular in shape) shown together with the set of all input and output signals associated with them. Figure E.5 illustrates a single element system.

FIGURE E.5
A SYSTEM

Mathematically, the system shown in Figure E.5 can be written as

$$\mathcal{A}: \quad x \longrightarrow y$$

The expression above is read as follows: $\mathcal{A}$ is the transformation by which x produces y. At this point, nothing more has been said about $\mathcal{A}$. All the reader knows is that it is the relationship between the two signals x and y.

Convention

a. **Shape:** While rectangular boxes are usually employed to illustrate systems, any closed shape will do, as long as it is not confusing to the reader. Often similar shapes are used to categorize similar systems appearing at different locations in a block diagram.

b. **Line Quality:** Systems are drawn using solid lines. However, it is often necessary to illustrate systems which are composed by aggregating other systems. Dashed lines are frequently used for this purpose. The type of dashed line may be varied to suit the user.

c. **Signal Location:** Input signals are usually placed into two categories: primary and secondary (or parametric influences). Generally speaking, inputs enter from the left, outputs exit from the right, and parameters from top and/or bottom. **Rarely do different types of signals contact the system diagram (box) on the same side!** Figure E.6 illustrates the convention.

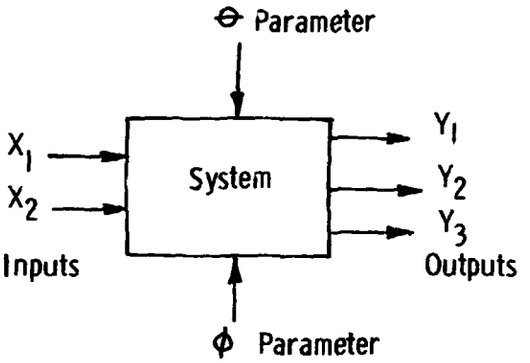


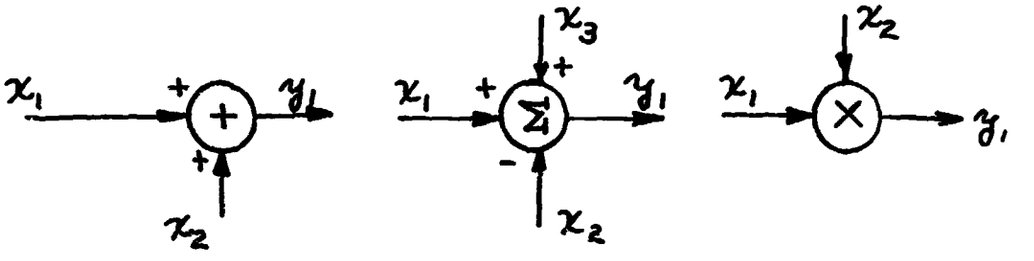
FIGURE E.6
SIGNAL LOCATION CONVENTION

The division of categorizing signals into primary (inputs) and secondary (parameters) must be a judgmental one. A guideline that is sometimes convenient is to ask the "all or nothing" question. If the system will continue to function when a variable or signal is reduced to nothing in a manner similar to its performance when that same signal is all there, then **most likely**, the signal in question affects response but does not cause it; hence it is a parametric signal. Obvious counter examples exist—the user should decide an operational way of categorization that seems to work for him.

Consistency Conditions

a. **Compatability:** The type of signal inputing to our system must match the type of signal the system is designed to transform in order that it be able to produce the type of output that is required. This seems obvious but systems are often inconsistently formed due to this shortcoming.

b. **Transformations:** All systems must represent transformations. Labels belong to signals, not transformations; that is, transformations must change or alter a signal or a set of signals.



(a) Addition (b) Summation (c) Multiplication

FIGURE E.7
EXAMPLES OF ALGEBRAIC OPERATIONS

III. Algebraic Operations

Algebraic operations are exactly that—transformations involving algebraic operations upon signals. Figure E.7 indicates examples for addition, (subtraction), summation, and multiplication. Care should be exercised to insure that these operations are used only in their literal sense. By this it is meant that it is incorrect to use summation to denote a new signal that is "somehow related" to the sum of two variables. For example, Figure E.7a illustrates

$$y_1 = x_1 + x_2$$

and **not**

$$y_1 = f(x_1 + x_2)$$

where f is some arbitrary function.

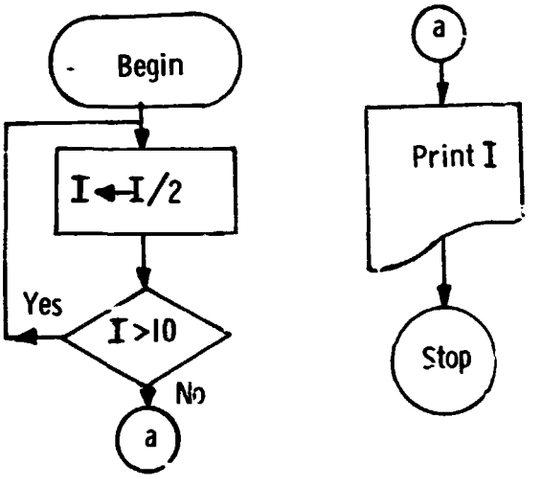
IV. Other Forms of Diagrams

In addition to block diagrams there are a number of other diagrammatic forms used to present information in a graphic form. A few of the more common diagrams are signal flow graphs and computer flow charts. Each form is intended to convey specific information in a convenient way.

Signal Flow Graphs

Signal flow graphs are the dual form of block diagrams. Each node (junction) represents a labelled signal, while the directed arrows represent system transformations. Figure E.8 illustrates a sample graph.

FIGURE E.9
SAMPLE COMPUTER FLOW CHART



Computer Flow Charts

Computer flow charts are used to indicate the sequential flow of command and computation that must be performed by a digital computer. The directed arrows indicate the position of the next sequential operation to be executed while the boxes indicate the operations to be performed. Shape is used extensively to denote the general type of operation. A sample chart is given in Figure E.9.

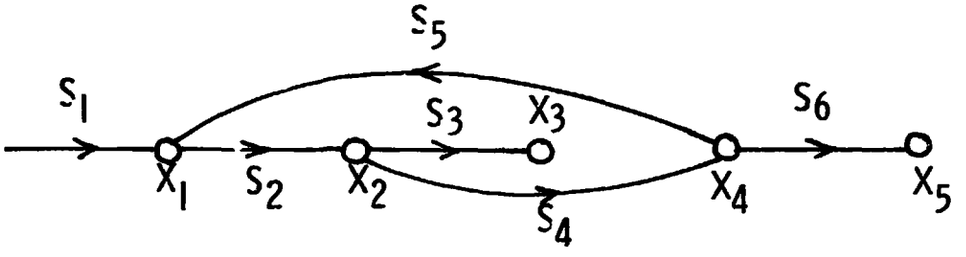


FIGURE E.8
SIGNAL FLOW GRAPH

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APPENDIX F

HUMAN RESPONSE TO ACCELERATION AND VIBRATION

Acceleration—General Comments

Much difficulty in assessing acceleration effects on man from available research literature stems from the frequent failure of investigators to develop and characterize data in terms of direction, magnitude, duration, and rates of buildup and decay of applied forces as well as the passenger's posture, seating conditions, and orientation to applied forces. Consequently, it is often difficult to correlate acceleration exposures, and especially the associated human responses, from among various researches. Moreover, lack of a clear distinction between response to acceleration and response to **rate** of acceleration results in a good deal of confusion over what has been observed or is being reported. These deficiencies inhibit understanding not only of extreme acceleration conditions (e.g., vehicle collisions) under which response is very strongly dependent on rate and duration of force application, but also of moderate conditions at levels affecting only comfort and annoyance.

There is further complication in assessing acceleration effects, namely that the accelerations experienced by the body and internal organs of a passenger may not be the same as, and are often larger than, the acceleration of the vehicle in which he is riding. Amplification of forces in a complex sprung-mass system such as the human body, is a well-known dynamic phenomenon. This relationship, however, is not very well delineated in the literature of acceleration effects on humans.

Extreme Acceleration

Available research literature on human response to acceleration has been concerned, for the most part, with what man **can** tolerate and very little with what man is **willing** to tolerate. Dealing mainly with problems in space flight, aviation, and automobile crash injury, the research has been aimed at exploring the physiological limits of man, short of death and serious injury, under impact loadings.

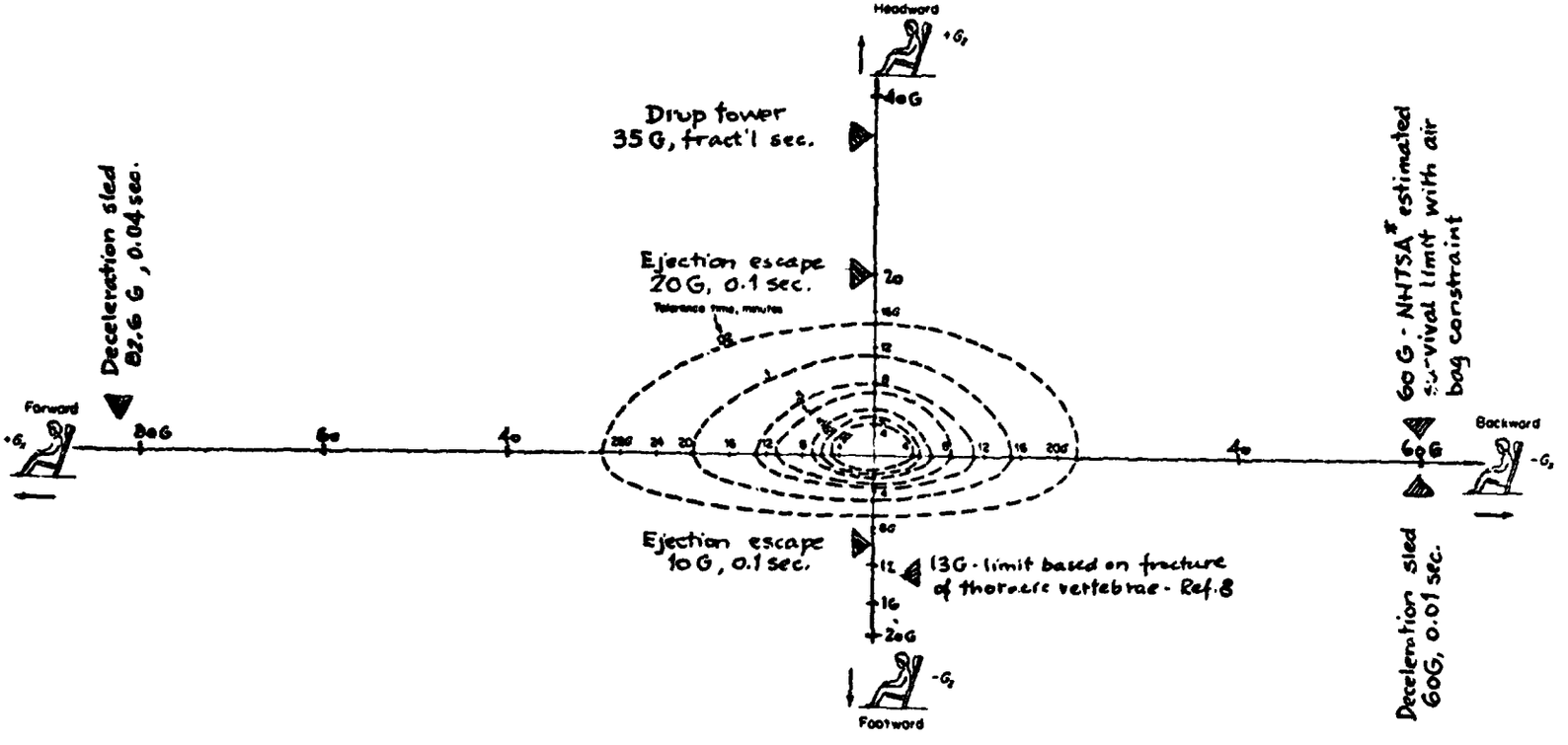
Some high-level acceleration exposures endured by human subjects are summarized in Table F.1 and selectively plotted in Figure F.1. The maximum acceleration loadings are of special interest. A variety of impact and deceleration experiences are summarized in Table F.2 and in Figure F.2. The direction of physiological acceleration is not provided, but may be surmised in most cases. Figure F.3 presents data from high-speed rocket

TABLE F.1
SOME MAXIMUM ACCELERATION EXPOSURES ENDURED BY HUMAN SUBJECTS

Type of G Field	Type of Maneuver	Peak G	Exposure Time (sec)	Type of Device
$+G_g$ (Transverse G, sternumward)	Abrupt deceleration	$82.6G_g$	0.04	Deceleration sled
	Abrupt deceleration	$55G_g$	0.01	Deceleration sled
	Abrupt deceleration	$35G_g$	0.12	Deceleration sled
	High-G re-entry	$25G_g$	5	Centrifuge
	Re-entry simulation	$15G_g$	5	Centrifuge
	Tracking and endurance test	$14G_g$	127	Centrifuge
	Tracking and endurance test	$10G_g$	210	Centrifuge
	Tracking and endurance test	$6G_g$	855	Centrifuge
$-G_g$ (Transverse G, spineward)	Abrupt deceleration	$-60G_g$	0.01	Deceleration sled
	Abrupt deceleration	$-38G_g$	0.12	Deceleration sled
	Endurance test in water capsule	$-31G_g$	5	Centrifuge
	Endurance test in water capsule	$-28G_g$	5	Centrifuge
	Re-entry simulation	$-15G_g$	5	Centrifuge
	Prolonged tracking and endurance test	$-10G_g$	71	Centrifuge
	Prolonged tracking and endurance test	$-6G_g$	350	Centrifuge
$+G_g$ (Positive G)	Ejection escape	$+20G_g$	0.1	Ejection tower
	Endurance, tracking	$+9G_g$	6	Centrifuge
	Endurance, tracking	$+8G_g$	26	Centrifuge
	Endurance, tracking	$+7G_g$	90	Centrifuge
	Endurance test	$+5G_g$	240	Centrifuge
$-G_g$ (Negative G)	Ejection escape (downward)	$-10G_g$	0.1	Ejection tower
	Push over	$-4.5G_g$	5	Airplane
	Endurance test	$-3G_g$	32	Centrifuge

Source: Chambers [2.14], Table 5, p. 213.

FIGURE F.1
LEVELS OF ACCELERATION, IN DIFFERENT DIRECTIONS, THAT CAN BE TOLERATED BY HUMANS FOR SPECIFIC PERIODS OF TIME BOTH VOLUNTARILY AND UNDER EXTREME CONDITIONS APPROACHING LIMITS OF SURVIVAL



Source: Adapted from McCormick [2.1], Fig. 17-8, as adapted from Chambers [2.14], Fig. 6

*NHTSA — Nat'l. Hwy. Traffic Safety Admin., U.S. Dept. of Transportation

FIGURE F.2

IMPACT AND DECELERATION EXPERIENCES. "APPROXIMATE SURVIVAL LIMIT" MUST BE USED WITH CAUTION, SINCE MANY BIOPHYSICAL CHARACTERISTICS INFLUENCE INJURY

Source: Webb [2.2], Fig. 5.2, p. 67

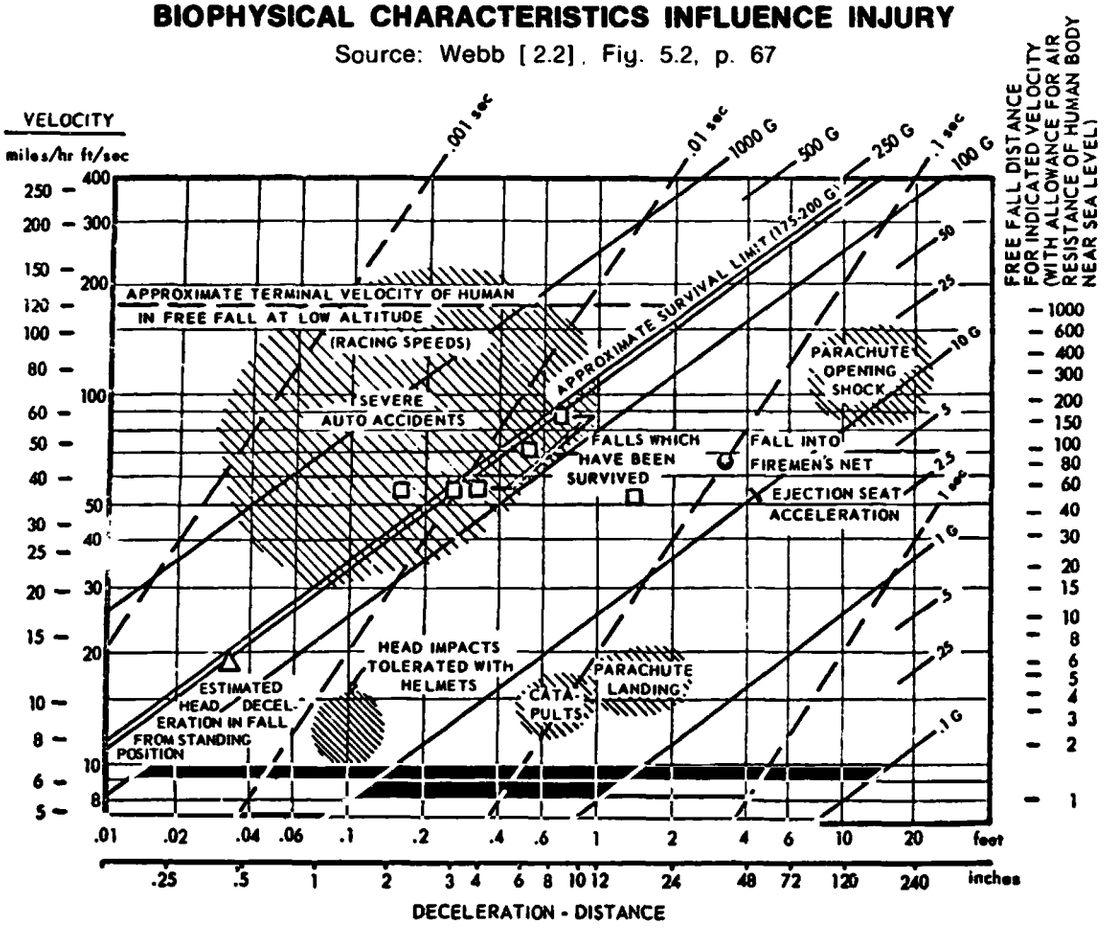


FIGURE F.3

PEAK TRANSVERSE -Gx AND -Gz ACCELERATION EXPERIENCES SURVIVED WITHOUT PERMANENT INJURY BY HUMAN SUBJECTS ON HIGH SPEED ROCKET SLEDS, AS ESTABLISHED BY J.P. STAPP

Source: Webb [2.2], Fig. 5.4b, p. 69

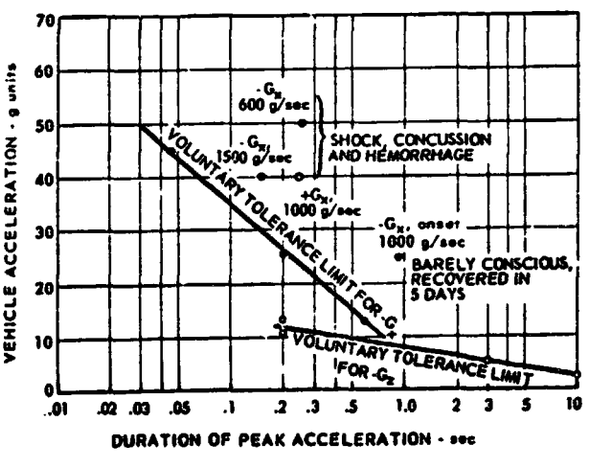


TABLE F.2
APPROXIMATE DURATION AND MAGNITUDE OF SOME SHORT DURATION ACCELERATION LOADS (FROM VARIOUS SOURCES)

Type of Operation	Acceleration (g)	Duration (sec.)
Elevators average in "fast service"	1- .2	1- 5
comfort limit	.3	
emergency deceleration	2.5	
Public transit normal acceleration and deceleration	1- 2	5
emergency stop braking from 70 m p h.	4	2.5
Automobiles: comfortable stop	.25	5- 8
very undesirable	45	3- 5
maximum obtainable	.7	3
crash (potentially survivable)	20-100	< 1
Aircraft ordinary take-off	5	>10
catapult take-off	2.5- 6	1.5
crash landing (potentially survivable)	20-100	
seat ejection	10- 15	.25
Man: parachute opening — 40,000 ft	33	.2- .5
6,000 ft.	8.5	.5
parachute landing	3- 4	.1- .2
fall into fireman's net	20	1
approximate survival limit with well-distributed forces (fall into deep snow bank)	200	015-.03
Head: adult head falling from 6 ft. onto hard surface	250	007
voluntarily tolerated impact with protective headgear	18- 23	02

Source: Table 5, Goldman and von Gierke [2.19]

sled tests and moreover gives some representative values of **rate** of acceleration (or "jerk").

In addition to the loadings shown in Table F.1, drop tests on human subjects in seated position, in which impact loading exceeded +35Gz for a fraction of a second, have been reported by Headley, et al [2.16]*. A search of the literature reveals few impact tests on humans subjected to lateral +Gy forces. Zaborowski [2.17]* reports 87 lateral acceleration tests with human subjects on a high-speed sled in which no permanent physiological damage was incurred for exposures of about 11.6 Gy and 0.1 seconds duration, and only minor complaints (e.g., neck muscle stiffness) occurred for exposures of about 8-9 Gy The subjects were healthy, young male volunteers fully restrained by lap belts and shoulder harnesses. Human tolerance to angular accelerations, particularly in combination with linear accelerations as occur in rollover type accidents, also has been little explored. Edelberg [2.18]* suggests theoretical limits for human tolerance to simple tumbling (about the y-axis) and estimates tolerances to combined tumbling and deceleration as may happen, for example, in spacecraft re-entry.

In general research has focused mainly on a few special seating configurations and force directions expected in space flight and frontal collisions of automobiles. A good deal is known about frontal (Gx) accelerations, but very little about lateral (Gy), angular, and combined accelerations. In tests on human subjects, especially at upper limits of tolerance, the subjects have been not only few in number, but have been carefully selected and trained individuals, such as pilots and astronauts, fully restrained by specially designed harnesses and seats for minimal risk of injury. These conditions are not representative of the average citizen using transport systems with typical seating arrangements. Moreover, ethical and legal limitations on tests with human subjects, and the desire to avoid death and permanent physical or mental impairment, have dictated great caution in testing human tolerance to impact. It is for the latter reason, of course, that the number of tests has been small and that much crash injury research has been performed with instrumented manikins or laboratory animals as surrogates for human subjects.

In spite of intensive study of anatomical consequences of impact, it has not been found possible to set clear criteria on physiological tolerance or to establish very much generally applicable knowledge of emotional, perceptual, and intellectual changes and impairments. On the other hand, human tolerance to high impact accelerations and the related physiological consequences have been sufficiently explored to be able to make at least gross estimates of outer limits of survivability Much remains of course, to be learned and understood.

Intermediate Acceleration

Aviation and space flight research into human response to acceleration has been largely concerned with intermediate levels of loading, sustained for a period of time longer than that for impact, which human subjects will endure voluntarily [2.14, 2.20]*. Such research has been conducted mainly with centrifuge machines having a passenger capsule that can be oriented in any given direction relative to the centrifugal force vector. "Voluntary" in this instance means that the test, once begun, can be stopped at will. In the rocket sled tests previously

reported, the term "voluntary" is taken to mean voluntary submission to the test by the subject (as opposed to accidental incidents), the subject having no control over termination of the test, once initiated.

Figure F.4 based on work by Chambers [2.14, 2.15]* shows approximate "best fit" curves applied to data from many centrifuge tests in which the test was stopped by the subject when he could tolerate it no longer or by a monitoring physician upon medical indications of serious distress. While these curves have been extended to times shorter than 0.03 seconds, the nature of centrifuge tests suggests that these data should not be regarded as impact loadings, as they are not associated with the characteristically high rates of onset of accelerations experienced in impact. It may be of interest to the reader to compare the data of Figure F.3 with those of Figure F.4. Figure F.5 shows upper limits of voluntary endurance as contrasted with the average tolerances shown in F.4.

Chambers' curves have been reinterpreted by McCormick [2.1]* and form the central group of isochrons reproduced in Figure F.1. Chambers' data, of course, pertain to accelerations along x- and z-axes only and not to diagonal vectors. Consequently, McCormick's extrapolation, although an intriguing concept, must be considered speculative in the absence of tests.

Figure F.6, similar in form to F.4 and incorporating extreme conditions of impact, summarizes peak transverse +Gx accelerations which have been survived by humans in cases of falls ($\sim$ 0.03 sec.), short-track impact facilities (0.03 to 0.1 sec.), high-speed sled runs (0.1 to 1.0 sec.) and centrifuge tests (2-1000 sec.). Accelerations lying below the data band are presumed to be non-injurious and those above to produce serious injury or death.

The passenger on conventional modes of transport seldom experiences acceleration forces of intermediate level and thus does not suffer difficulties with task performance or judgment. Aircraft in clear air turbulence may cause passengers to be subjected to such forces, but the discomfort, alarm, and possible injury attendant upon that violent circumstance far overshadow effects such as disorientation and visual illusion. In general, accelerations of intermediate level are of little concern in ordinary transportation systems and seldom require consideration in their design.

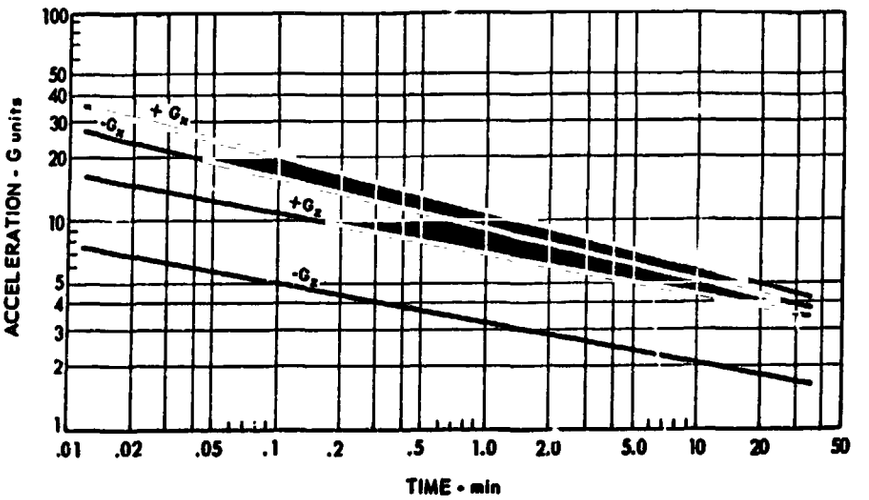
Clinical manifestations of distress, the nature of which affect acceleration endurance limits, are—grossly speaking—cardiovascular incidents causing chest pain and pulse rate changes for +Gx, grayout and then blackout for +Gz resulting from loss of blood to the head, and eye hemorrhaging ("redcut") and a feeling of bursting for -Gz resulting from excessive blood in the head and upper trunk. All are more or less accompanied by respiratory difficulties and loss of vision, the latter due to both improper blood circulation and mechanical distortion of the eye structure. Chambers [2.14, 2.15] and Webb [2.2], among others, summarize many of the medical effects associated with acceleration exposures.

Mild Acceleration

Using an approach similar to that described in Chapter 2, the Japanese National Railroad (JNR) has established operating limits on accelerations for the New Tokaido Line and for proposed new rail routes. The acceleration limits in Table F.3 for advanced high-speed trains and TACV systems, also have been derived from this kind of analysis, as a comparison with the foregoing values will show. In Table F.3, the unexplained difference between emergency limits for the two systems is thought to reflect a decision to allow standing passengers on high-speed rail, but only seated passengers on TACV systems.

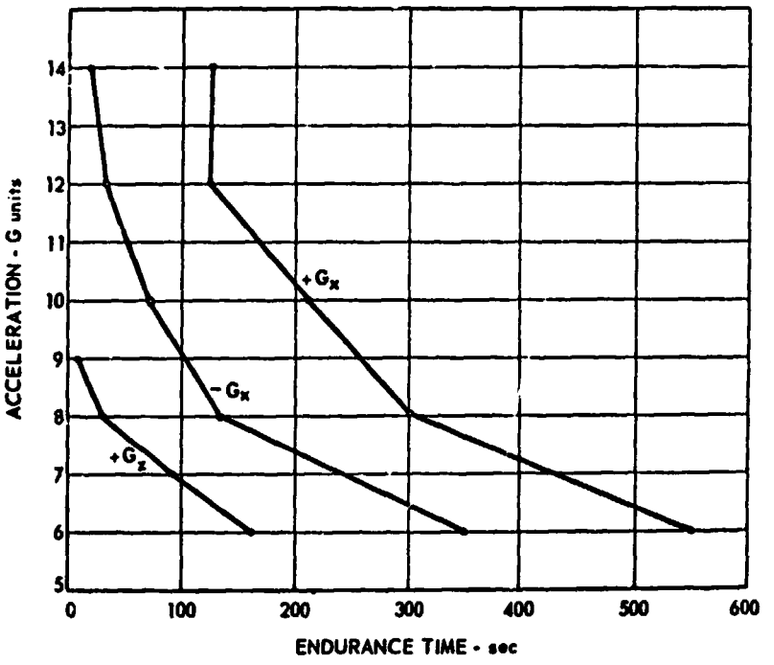
Very much the same figures for acceleration limits have been recommended or specified for other proposed ground transport modes. For suspended monorail systems, Pei [2.38] recommends the following acceleration limits: 0.07g longitudinal, 0.08g lateral, 1.0+0.07g vertical, and 0.15g emergency braking, which appear to stem directly from the detailed studies of reference [2.13]. Limits for Personal Rapid Transit (PRT)

FIGURE F.4
AVERAGE VOLUNTARY ENDURANCE OF ACCELERATION



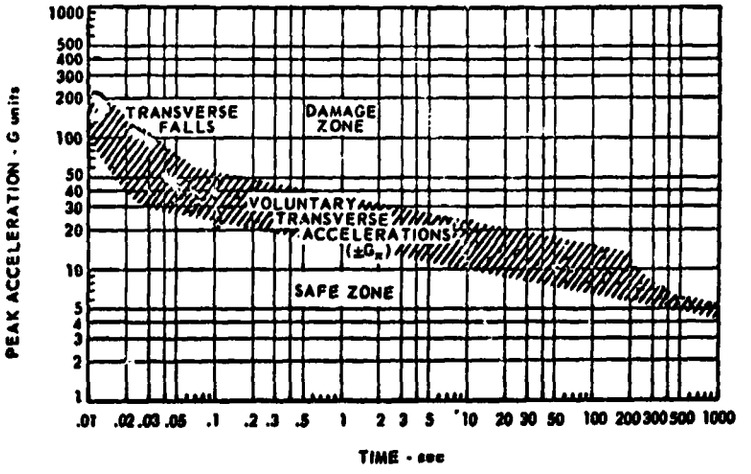
Source: Chambers [2.14, 2.15]

FIGURE F.5
UPPER LIMITS OF VOLUNTARY ENDURANCE OF ACCELERATION



Source: Chambers and Hitchcock [2.21]

FIGURE F.6
PEAK TRANSVERSE ACCELERATIONS SURVIVED WITHOUT PERMANENT INJURY. DATA FROM FALLS (0.03 SEC.), SHORT-TRACK IMPACT FACILITIES (0.03 TO 0.1 SEC.), HIGH SPEED SLED RUNS (0.1 TO 1.0 SEC.) AND CENTRIFUGE TESTS (2-1000 SEC.)



Source: Webb [2.2], Fig. 5.4a, p. 69

TABLE F.3
SOME RECOMMENDED SYSTEM DESIGN CRITERIA FOR PASSENGER ACCELERATION LIMITS

	High-Speed Rail Systems (Reference 2.13)		Tracked Air-Cushion Vehicle Systems (Reference 2.36)	
	Normal	Emergency	Normal	Emergency
Backward longitudinal acceleration (-Gx) (1) (4) (5)	0.07	0.15	0 07	0.30
Forward longitudinal acceleration (+Gx) (2)	0 09	0.15	0.09	0.35
Lateral acceleration (+Gy)	0 08(3)	0.15	0.08	0 20
Vertical acceleration (+Gz)	1 0+0.07	1.0+0.15	1.0+0.07	1 0+0.15
Backward longitudinal jerk (-Gx/sec)	0.06	0.10	0 06	0.60
Forward longitudinal jerk (+Gx/sec)	0.06	0.10	0.06	0 60
Lateral jerk (+Gy/sec)	0 04	0.10	0 06	0 50
Vertical jerk (+Gz/sec)	-	-	0 04	0.20

Notes (corresponding to parenthetical numbers above).

1. Forward acceleration, passengers facing backward; braking, passengers facing frontward.
2. Forward acceleration, passengers facing frontward; braking, passengers facing backward.
3. Limit of 0.08g lateral acceleration on curves likely to be comfortable for at least 95 percent of passengers, seated or standing. TRW [2.13] suggests a limit of 0.10g for lateral force on seated passengers in a train standing still on a superelevated curve
4. Smith [2.35] , Director, British Railways Research Dept., suggests braking limits for an "advanced passenger train" (155 mph): 0.075g, normal braking; 0.15g for "adverse signals"; 0 3g maximum emergency braking
5. TRW [2.13] suggests an absolute maximum limit of 0.3g for emergency braking, should higher values be obtainable This limit can be exceeded, for example, for complete propulsion power failure of tracked air-cushion vehicles at high cruise speeds, unless track sliding friction can be reduced

TABLE F.4
ACCELERATION UPPER LIMITS FOR PERSONAL RAPID TRANSIT VEHICLES

	Deceleration-Acceleration g and (ft/sec²)	Jerk g/sec and (ft/sec³)
(a) As specified for PRT demonstration at "Transpo 72," Dulles Airport		
Emergency braking	0.30 (10)	0.20 (7.0)
Normal operating conditions		
longitudinal	0.12 (3.75)	0 09 (3.0)
lateral	0.08 (2 60)	0.03 (1.0)
vertical	0.08 (2.60)	0.03 (1.0)
(b) Current proposals for generic PRT systems (standees permitted)		
Emergency braking	0.30 (10)	0 40 (12.9)
Normal operating conditions		
longitudinal, lateral and vertical	0.125 (4.0)	0.10 (3.2)
(c) Morgantown, W. Va PRT demonstration project		
Emergency braking	0.30 (10)	
Normal starting	0.0625 (2.0)	0.10 (3.2)

Sources: a) Reference 2.39, Secs. 4.3.1.2 and 4.3.2.4
b) U.S. Dept. of Transportation, internal memoranda, June, 1972
c) Office of Morgantown Project, UMTA, U.S. DOT, by correspondence

vehicles, as specified or proposed by the U.S Dept of Transportation, are summarized in Table F.4 and may be considered more or less typical for various proposed versions of PRT systems in spite of the variation in values.

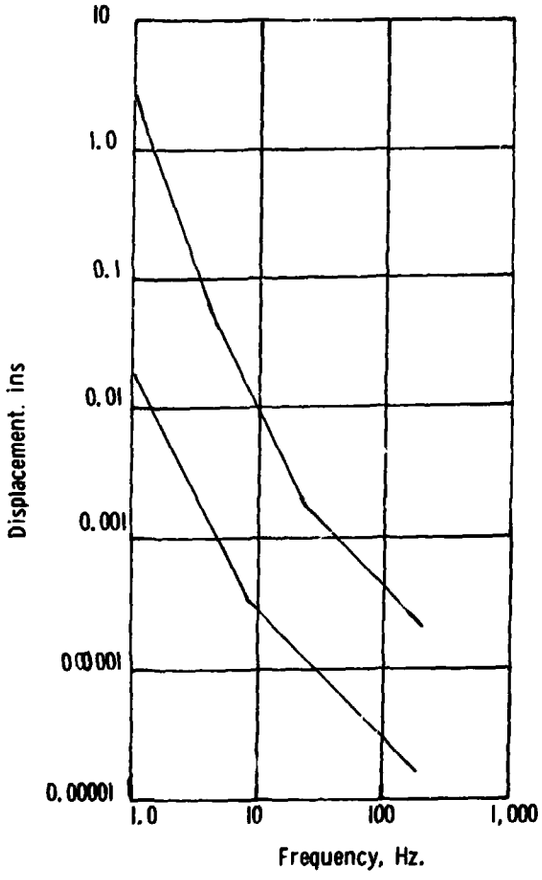
Several other observations may be made at this point in reference to the JNR data and the 70-percent baseline analysis given above First, accelerations somewhat higher than those suggested may be rated acceptable by passengers if the acceleration or deceleration is smooth with small jerk This effect is not well brought out in the research literature, but is suggested implicitly in a number of references.

Second, acceleration much larger than those suggested for "emergency conditions" may be tolerable because, in emergencies, they occur infrequently and have more to do with physical safety than with comfort. One option for setting higher limiting accelerations is to set the emergency condition at level 4 (or higher) (See Figure 2.3 for definition of levels.) Another option is to examine experiences with acceleration exposures, such as those given in Table 2.3, and to set upper limits for design arbitrarily at values known to be within limits of human tolerance and safety It is known, for example, that full emergency braking of automobiles can produce accelerations of the order of 0 7g-1.0g without injury to occupants, especially when lap-belt or shoulder-harness restraint is provided. To presume that passengers on other modes of transport can sustain the same level of acceleration seems most reasonable. It is not surprising, then, to find maximum emergency braking decelerations of 0.3g commonly recommended for various forms of ground transportation Whatever approach is used, the definition of "emergency condition" and the setting of acceleration limits require some care and judgment.

Third, there is no good reason why the percentage of passengers satisfied should be the same at both normal and emergency conditions, as the 70 percent illustrated above. It would be equally valid to satisfy, say, 90 percent at level 2 and 50 percent at level 3, or to use other reasonable combinations

Fourth, the data of Figure 2.3 apply strictly only to seated passengers of Japanese extraction on Japanese railroads Data on standing passengers, as given in reference 2 9, must be examined also if operating conditions of the vehicle allow some passengers to stand While it is reasonable to assume that Japanese railroad

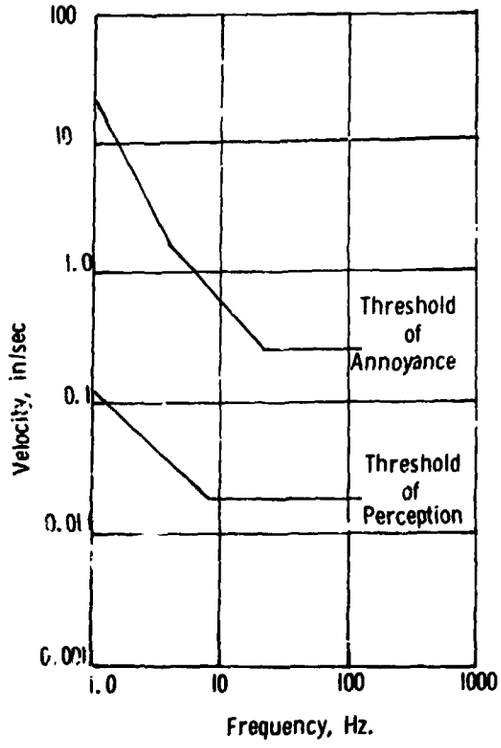
FIGURE F.7



THRESHOLDS OF VIBRATION PERCEPTION AND ANNOYANCE REFERRED TO DISPLACEMENT AND FREQUENCY

Source: [2.41]

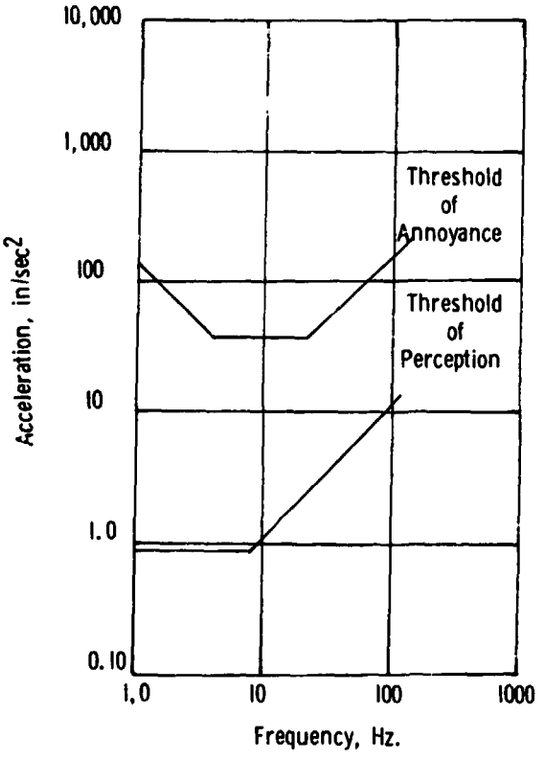
FIGURE F.8



THRESHOLDS OF VIBRATION PERCEPTION AND ANNOYANCE REFERRED TO VELOCITY AND FREQUENCY

Source. [2.41]

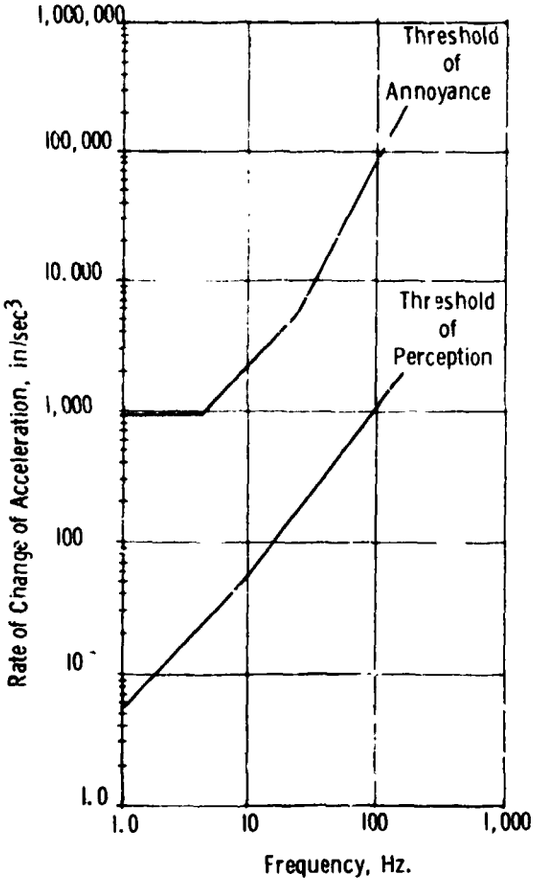
FIGURE F.9



THRESHOLDS OF VIBRATION PERCEPTION AND ANNOYANCE REFERRED TO ACCELERATION AND FREQUENCY

Source: [2.41]

FIGURE F.10



THRESHOLDS OF VIBRATION PERCEPTION AND ANNOYANCE REFERRED TO RATE OF CHANGE OF ACCELERATION AND FREQUENCY

Source. [2.41]

equipment does not differ significantly from American counterparts, it is not quite so easy to extrapolate from the average Japanese passenger to the average American passenger who is larger in stature and who may have a much different distribution of body mass and different dynamic characteristics. As a consequence of such differences, Americans may very well rate a given acceleration less comfortable than Japanese do. Again, caution and judgment are called for in the use of available data on subjective response to acceleration.

Finally, subjective response of railroad passengers cannot be directly transposed to other modes of transport, such as aircraft or ships, although the data may provide valuable guidance to the designer, especially when modal characteristics do not differ very much. The values of Table F.3, for example, are credible because advanced high-speed railroads and even TAC vehicles are similar in many ways to conventional railroads. However, this problem of transposition of data has special significance for the design of new modes of transport, for which there is no record of experience or history of user acceptance, and for which subjective testing of ride quality cannot even be done, simply because the mode has not yet been built.

Vibration

Research on human subjects has not explored the ultimate limits of the capacity of men to withstand vibrations. However, some work with animals has been done [2.47] which gives an indication of what one might expect if men were exposed to severe vibrations. Generally the results may be described as severe internal bruises and hemorrhaging. Effects of this nature are, of course, far beyond the results expected from normal riding in a conventional vehicle, although farm tractors can approach such limits; acceptable vibrations in a transportation vehicle occur at the opposite end of the scale. What are the smallest perceptible vibrations? What are the values of frequency and amplitude which define the boundary of "annoying" vibrations when a passenger is subjected to the environment for a few minutes or a few hours? Soliman [2.41] has summarized a large volume of research data to 1968, covering pure sinusoidal vibrations

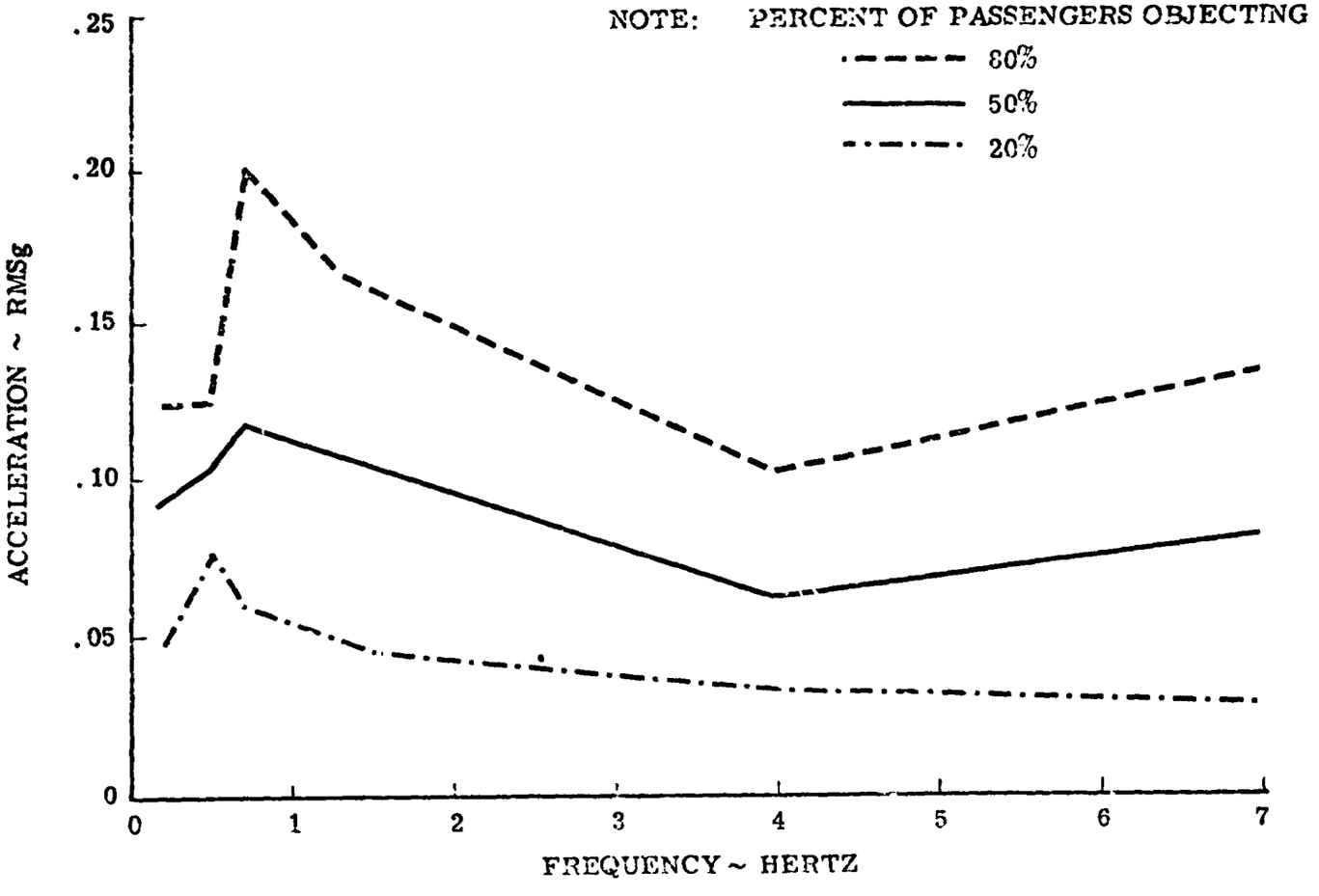


FIGURE F.11
VERTICAL ACCELERATION OBJECTIONABLE THRESHOLDS FOR PASSENGER RIDE

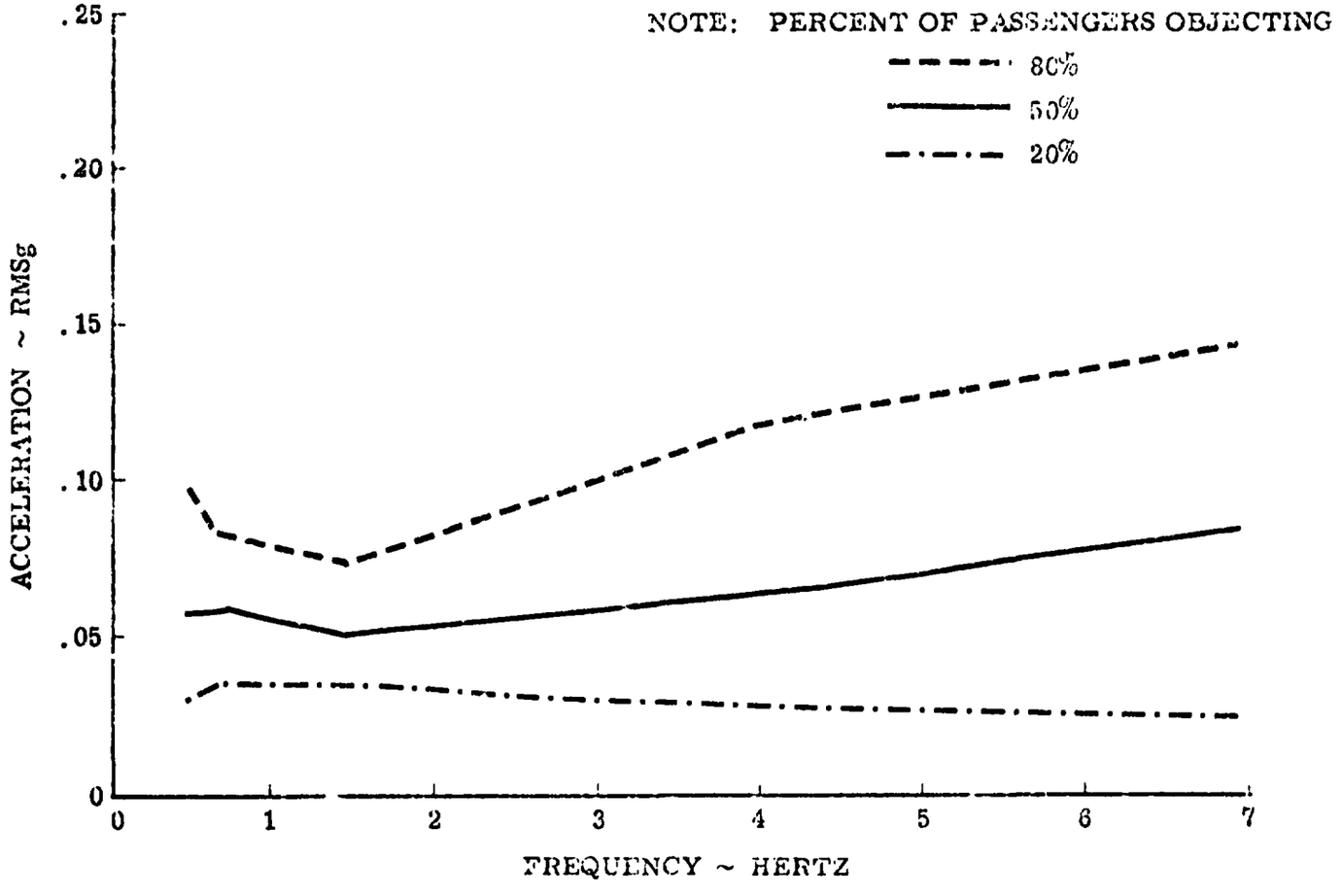


FIGURE F.12
LATERAL ACCELERATION OBJECTIONABLE THRESHOLDS FOR PASSENGER RIDE

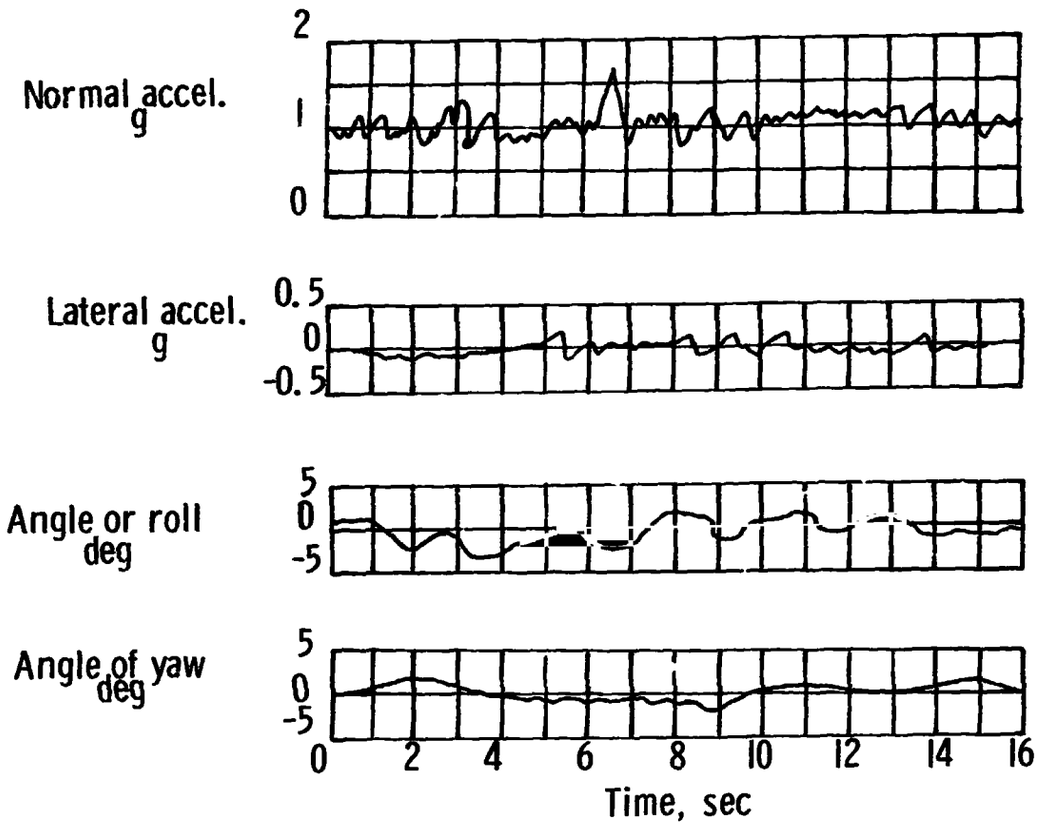


FIGURE F.13
MOTION OF AN AIRPLANE IN ROUGH A I

over a range of 1 to 200 Hz, and concentrating on demarcations of perceptibility and annoyance.

His averaged data are given in Figures F.7, F.8, F.9, and F.10 which depict effects of vertical vibration upon perception and annoyance. Tolerance to vertical vibration is found to be greater than horizontal vibration in either direction and the least tolerance is to lateral vibrations. Figure 2.7 indicates levels and effects in more extreme cases.

Two points should be made with respect to the above. One is that the results shown are averaged from a large number of experiments which were not conducted under identical conditions. There is a substantial variation among individuals in their tolerance to vibration. Holloway and Brumaghim [2.48] show results of tests, Figures F.11 and F.12, indicating the variation in acceptable levels of vibration for seated subjects. The second point to be made is that it is not clear how one should apply single frequency, single axis test data to situations of random vibration occurring in several degrees of freedom as indicated by Figures 2.5 and F.13. Holloway and Brumaghim [2.48] have carried out one series of tests in which subjects were exposed to two axis multifrequency vibrations. The results, which must be considered preliminary are indicated by Figure F.14.

The influence of rotational contributions has not been explored: there is no well developed and documented way to include intermittent vibrations which may be very influential in determining subjective ride quality; and there is no method available with which to assess the influences of the purpose of travel or other individual traveller characteristics which will lead to variations in subjective ride quality evaluations

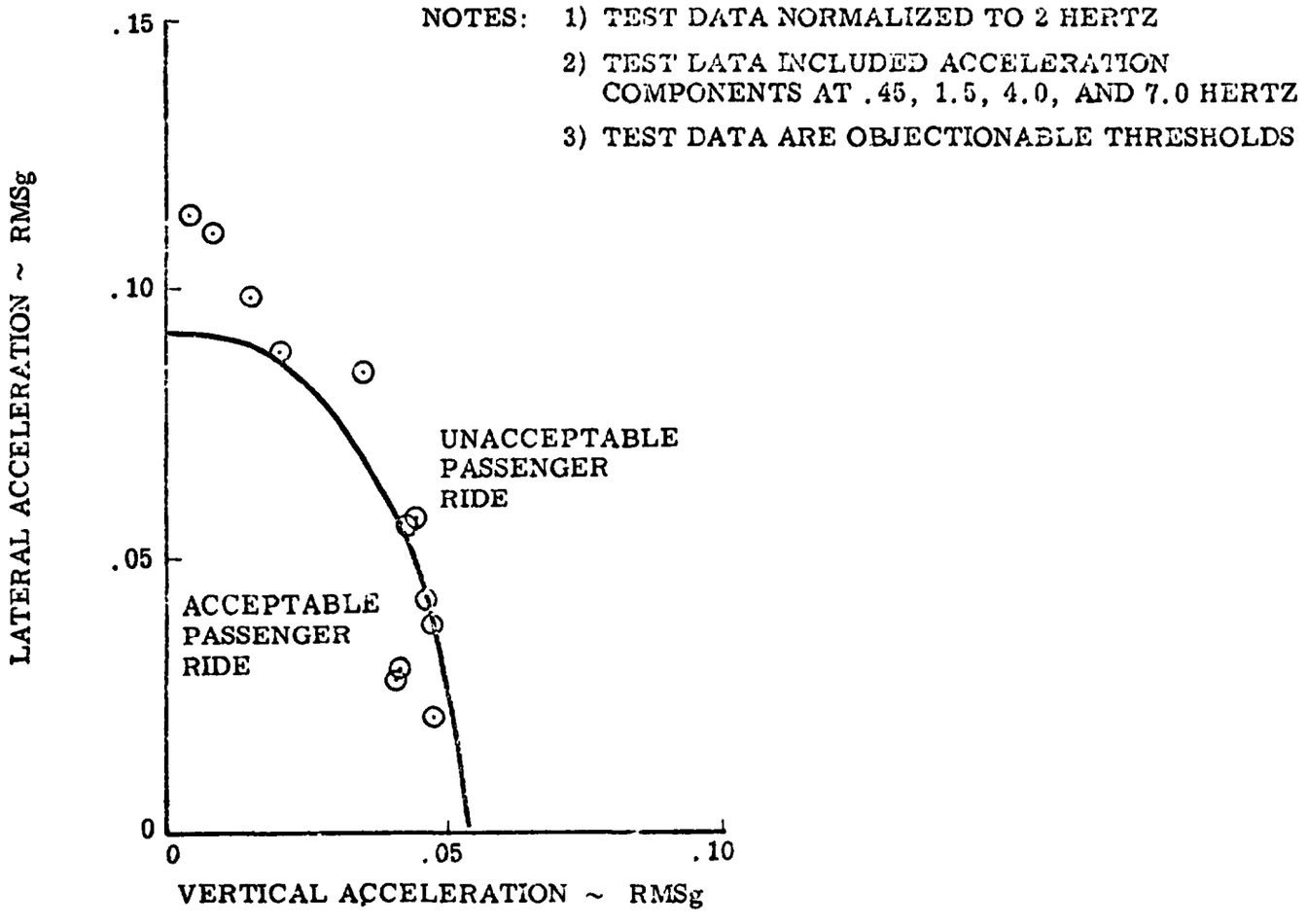


FIGURE F.14
COMPARISON OF DUAL AXIS VIBRATION TEST RESULTS TO RIDE COMFORT CRITERION

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APPENDIX G

TORPOR AND TEMPER ON WEST OCEAN VIEW AVENUE

Congestion on city streets is somewhat less than exceptional, rather, it is accepted as the norm But the magnitude of duress created by returning to Hampton, Virginia, from Virginia Beach or Norfolk on any Sunday afternoon in summer is nothing short of awesome As if on cue, literally thousands of beach-goers drive en masse toward the Hampton Roads Bridge Tunnel, the only connector between Norfolk's Willoughby Spit and Hampton, America's oldest continuous English speaking settlement

Yes, the drive from Norfolk to Hampton, ordinarily a reasonably pleasant excursion through a tunnel and bridge combination spanning the expansive and busy waters of Hampton Roads becomes transformed by sheer numbers of motorists into a veritable nightmare For a distance of five miles leading to the water, the four-lane highway in its northbound lanes during peak hours is deluged by wheeled vehicles idling with occupants and engines heating up to frightful proportions Because automobile air-conditioners cease to function after a short period of idling, every attempt at creature comfort in such circumstances seems thwarted With windows and doors open, both driver and rider vainly seek sea breezes or the turbulence of tractor trailers as they mercifully speed past in the opposite direction.

The bored motorist, seeking diversion as his "Hot" light gleams menacingly from the dashboard, can take solace in the scenes immediately surrounding his centrally located parking (i.e., idling) space Gazing directly ahead, he might observe an equally harried driver employing his respite by emptying ash trays onto the pavement. Or to his right, he might see a swim-suit-clothed family becoming progressively more frustrated in their uncomfortable pilgrimage to home and shower. In his rear-view mirror, our static driver might see his counterpart frantically seeking a last whiff of air-conditioned air before fear of overheating overcomes his desire for comfort

Hence, with thousands of other drivers and riders also enmeshed by vehicular pollution, our driver delicately alternates his right foot between accelerator and brake pedal to propel himself and his passengers at a clip of one mile per hour. If his own contained hostility were not enough, he would sit in fascinated, almost pathological amazement at the sight of small children skipping along the sidewalks well in advance of his 250-horsepower transportation machine A mixture of disgust and envy permeates his being as he watches also cyclists (motorized and otherwise) zip rapidly and gingerly forward through the scanty middle lane between the lengthy column of bulkier vehicles He thinks, "It's easier for a camel to pass through the eye of a needle than . " Ah, the virtues of stoicism.

Those ahead of our driver begin to weaken They leap from their cars, sprinting to the ever-beckoning 7-Eleven stores lining the route. While a relief driver inches the car forward, these enterprising temporary pedestrians return invigorated to their automobiles laden with "Slurpees" and other beverages Time elapsed in the operation—three minutes Forward distance covered—forty-seven feet. Thus, bolstered by a brief EVA (courtesy of NASA), the hardier motorists resume their initial status of creeping toward freedom in the form of the bridge-tunnel

Further along, and much later, our persevering driver squints his eyes into the setting sun hoping against hope that his caravan is within sight of the end Accepting only the consolation that many others share their fate, our exhausted occupants huddle ever closer to the windows opened against suffocation. Suddenly a car to the right begins hissing smoking, and lurching, then it expires, roiling slowly to the shoulder of the road With radiator boiling its occupants hurtle themselves onto the sidewalk assume an ambulatory stance, and stretch stiffened limbs in the direction of the nearest friendly neighborhood service station, located at least a mile away in the opposite direction from the bridge

With increasing trepidation, our driver and riders push onward until at last, gleaming white on green they sight the letters HAMPTON ROADS BRIDGE TUNNEL. But before admission to it, they must traverse a harrowing stretch of highway in which the right lane becomes increasingly narrow as it eventually merges into the left Hence, two lanes of choked traffic must become one, cajoled by a squadron of state troopers frantically waving motorists onward and closer into a single file of traffic which becomes the solitary lane in each direction or the bridge-tunnel itself

As the sun sinks slowly in the west and with feverish anticipation of accelerating the car to a speed in double figures for the first time in recent memory, our driver is able to begin counting the cars directly ahead of his path to the bridge. When the total nears ten, he knows that he will endure; he will make it after all! After at least two hours of agony, the ecstasy of the open road looms promisingly in the psyche of the motorist "Seven, six five, soon it will be my turn!" Yes, it comes at last Like a sprinter bursting from the starting blocks, he lurches his vehicle onto the causeway which winds its way out from the land and over the water of Hampton Roads. Only five miles to cover now, and the shores of Hampton will be realized at last

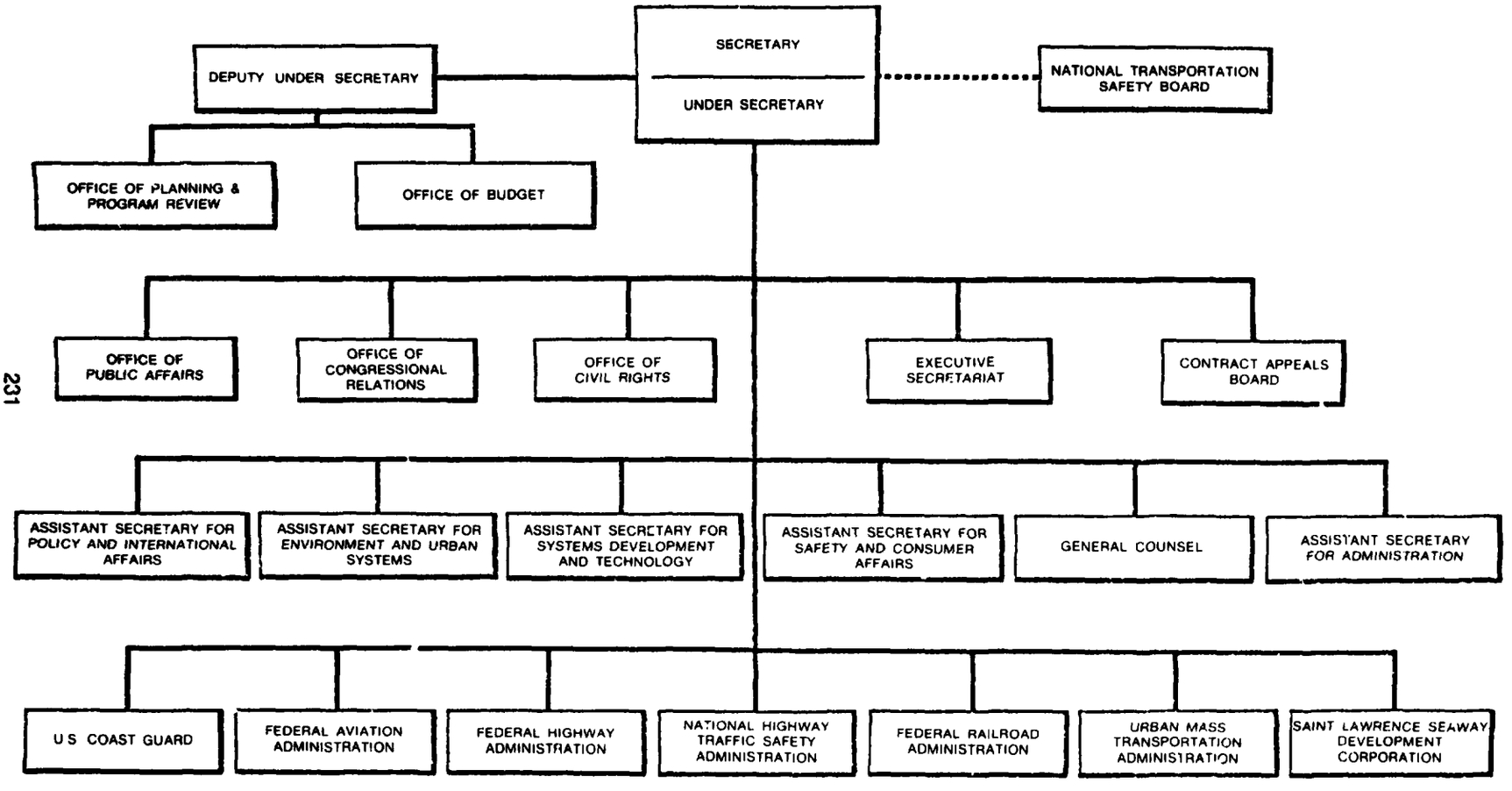
But, alas, even here amidst the undulating blueness and crimson evening sky, serious restraints impinge upon the driver's desire to flee from the teeming roadways of Norfolk Similar restraints exist here just as they did "over there." For the single lane in the westerly direction is unable to handle the overload which returning surfers and sun lovers afford. Consequently, there are long periods of hesitation, even absolute cessation of movement, as the motorist may now stare longingly at the sailboats making considerably better time than he in traversing the span of water over which he intermittently pauses and starts

Even when the decline of the tunnel is reached and the roadway enters it, the traffic movement is impeded by such factors as claustrophobia which bring the foot of many a driver to the brake more often than to the accelerator. Hence, the mile-and-a-half journey under the water becomes a noisy and disarming interlude in the overall experience of travelling in this place at this time

Shining sardonically all along the walls of the submarine roadway are signs reading, "Keep Up Speed" or "40 Miles Per Hour " The final touch of irony is provided by four uniformed guards who are posted strategically along the side rails waving white gloves tremulously for motorists to keep up with the car ahead. (At three miles per hour or less, this presents little challenge.) One could only postulate on the level of verbal abuse to which these hapless servants of the Virginia Department of Highways are subjected as they perform their futile duty.

The surface at last gained, the motorist has only a mile or so of "open bridge to negotiate before his incredible trip to Hampton culminates Yet even here, one major obstacle remains to harass the drivers and riders of Detroit's best (substitute Japan's or West Germany's if you prefer) After arriving at the toll plaza and enduring another agonizing delay (due in part to the invariable closing of one northbound toll both), the driver is relieved of $1 25 This he deposits into the listless palm of the attendant who by this time is equally as surly as our driver, a portion of whose life we have shared on this summer weekend Anyone for renovating the old ferryboats? Yea verily!

APPENDIX H
DEPARTMENT OF TRANSPORTATION



ORGANIZATIONAL CHART OF THE U.S. DEPARTMENT OF TRANSPORTATION

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APPENDIX I

ORGANIZATION OF STUDY TEAM

In order to proceed as efficiently as possible toward the ultimate goals within eleven weeks, the study-design activity was organized during successive phases of the program in the following manner

The participants were initially organized into two basic groups for preliminary study. These two groups were:

Transportation Modes (Current Status)

G. P. Fisher, Chairman
J. B. Barlow
J. P. McCrory
R. L. Rosen
G. M. Swisher
C. M. Was
J. C. Winfrey

Human Factors (State of the Art)

S. K. Adams, Chairman
A. L. Burgett
A. L. Chaikin
J. C. Free
R. W. Griffin
L. L. Hoag
D. H. Rothenberg

A committee was established during the second week for the purpose of recommending the scope and the constraints of the investigation.

Scope Committee

A. L. Chaikin
G. P. Fisher
D. H. Rothenberg

As a result of the studies of these invited groups, a further delineation was necessary. These task groups were functional from week 3 to week 9, and their purposes and functions were as follows:

Transportation Systems Survey

G. P. Fisher, Chairman
J. B. Barlow
L. L. Hoag

Psychological and Physiological Human Factors

G. M. Swisher, Chairman
S. K. Adams
A. R. Chaikin
L. L. Hoag

The Transportation Scene Actors

J. P. McCrory, Chairman
R. W. Griffin
A. E. Millar, Jr.
C. M. Was

Socio-Economics of Transportation

J. C. Winfrey, Chairman
A. L. Burgett
R. W. Griffin
R. L. Rosen

Environmental Designed Transportation Planning

J. C. Free, Chairman
J. B. Barlow
D. H. Rothenberg
C. M. Was

Systems Design For Transportation Management

D. H. Rothenberg, Chairman
S. K. Adams
A. L. Burgett
A. R. Chaikin

During the last four weeks of the program, the following Standing Committees were necessary

Oral Presentation Committee

J. C. Winfrey
S. K. Adams
L. L. Hoag

Illustrations Committee

G. M. Swisher
D. H. Rothenberg
L. L. Hoag

Editorial Committee

A. E. Millar, Jr., Editor-in-Chief
R. L. Rosen
J. D. Gibson
R. G. Crum

During the 8th through the 11th weeks, the results of these task groups were incorporated into the major sections of this report. The following "section editors" coordinated this material.

Prologue: Mobility and Life . . . . . A. E. Millar, Jr
Summary of Recommendation . . . . . R. L. Rosen
1—Mobility: Promises and Problems . . . J. B. Barlow
2—Mobility and People . . . . . G. P. Fisher
3—Mobility and Society . . . . . J. P. McCrory
4—The Environmental Cost of Mobility . . . . . D. H. Rothenberg
5—The Circulatory System and Its Constrictions . . . . . A. L. Burgett
6—Systems Design: Methodology for Transition . . . . . J. C. Free
7—Conclusions and Recommendations . . . . . R. L. Rosen
Epilogue . . . . . A. R. Chaikin
Appendices . . . . . S. K. Adams